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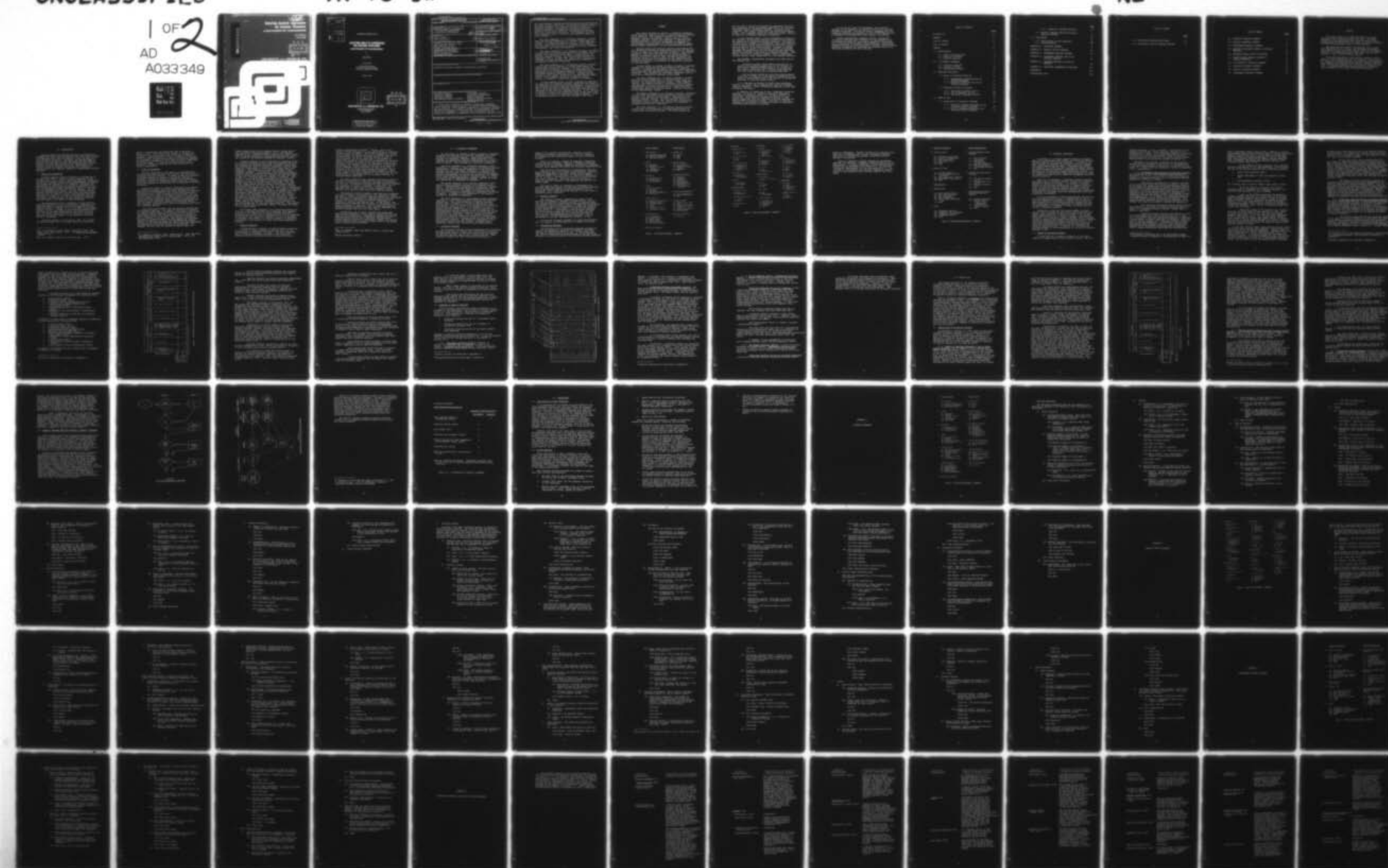

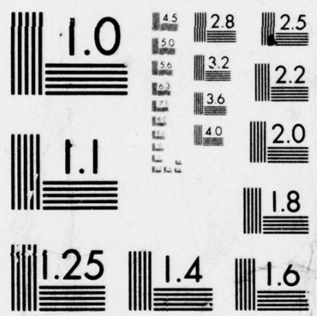

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TECHNICAL REPORT 76-10

SELECTING ANALYTIC APPROACHES FOR DECISION SITUATIONS

A MATCHING OF TAXONOMIES

by

Rex V. Brown
Jacob W. Ulvila

Sponsored by

Office of Naval Research
Engineering Psychology Programs
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October, 1976

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This report attempts to develop a conceptual framework within which the state-of-the-art of applied decision analysis can be codified. The framework consists of a three-way taxonomy: decision situations, analytic options, and performance measures. Within this framework, a tentative and illustrative set of practical guidelines is presented to help decision analysis users
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and practitioners identify appropriate analytic approaches for any given decision situation. An attempt is made to suggest a taxonomic framework for codifying the state-of-the-art of decision analysis, a language for expressing 'matching generalizations' which associate the appropriate analytic option to a particular situation. This language has three main components, each of which has an exhaustive numerical coding scheme.

The first component is a "situation taxonomy," listing about one hundred dimensions of a situation that might be relevant to a particular analytic choice. These dimensions include: the stakes involved in a decision; the reaction time available; and the clarity with which options, probable consequences, and values are perceived.

The second component is an "analysis taxonomy," according to which about one hundred decision-analytic choices can be located in an "analytic option space." Dimensions of the analytic taxonomy include: how much decision analysis is undertaken, how it is used, what type of model structure is involved, and what technique for probability assessment or consequence evaluation is employed.

The third component is a "performance measure taxonomy," listing about thirty measures of effectiveness which can characterize the analytic options. The same taxonomy can also be used to describe a situation by expressing the relative importance of the performance measures in the situation. Performance measure dimensions include: enhanced logical reasoning, cost, speed, convenience, and facilitated communication. This component serves as a mediating factor, implicit or explicit, in matching analysis to situation.

In this research effort, we have attempted to identify a few important and plausible matching generalizations based on the experience of practicing decision analysts. A few analytic options were selected to represent thousands of possibilities and to facilitate generalizations about when they should be exercised in the form of a taxonomy matching. A U.S. decision on whether to export high-technology items to the Soviet Bloc is analyzed by using the taxonomic framework. Other illustrative material is also used throughout the report.

SUMMARY

This report attempts to develop a conceptual framework within which the state-of-the-art of applied decision analysis can be codified. The framework consists of a three-way taxonomy: decision situations, analytic options, and performance measures. Within this framework, a tentative and illustrative set of practical guidelines is presented to help decision analysis users and practioners identify appropriate analytic approaches for any given decision situation.

Decision makers and decision analysis practitioners are both faced with problems of determining what type of analysis, if any, to apply to a given decision situation. The standard approach in such cases has been for the decision maker or analyst to evaluate, case by case, any special features of the situation and for him to apply informal experience and judgment, reflecting his perception of the state-of-the-art of decision analysis, to determine the appropriate approach for the situation.

In this report, an attempt is made to suggest a taxonomic framework for codifying the state-of-the-art of decision analysis, a language for expressing "matching generalizations" which associate the appropriate analytic option to a particular situation. This language has three main components, each of which has an exhaustive numerical coding scheme.

The first component is a "situation taxonomy," listing about one hundred dimensions of a situation that might be relevant to a particular analytic choice. These dimensions include: the stakes involved in a decision; the reaction time available; and the clarity with which options, probable consequences, and values are perceived. These dimensions collectively define a "situation space" in which a situation can be unambiguously located.

The second component is an "analysis taxonomy," according to which about one hundred decision-analytic choices can be located in an "analytic option space." Dimensions of the analytic taxonomy include: how much decision analysis is undertaken, how it is used, what type of model structure is involved, and what technique for probability assessment or consequence evaluation is employed.

The third component is a "performance measure taxonomy," listing about thirty measures of effectiveness which can characterize the analytic options. The same taxonomy can

also be used to describe a situation by expressing the relative importance of the performance measures in the situation. Performance measure dimensions include: enhanced logical reasoning, cost, speed, convenience, and facilitated communication. This component serves as a mediating factor, implicit or explicit, in matching analysis to situation.

In this research effort, we have attempted to identify a few important and plausible matching generalizations based on the experience of practicing decision analysts. The generalizations do not attempt to be exhaustive, much less definitive. To do so would require formally codifying the entire current state-of-the-art of decision analysis. Instead, an attempt has been made to select a few analytic options to represent thousands of possibilities and to generalize about when they should be exercised in the form of a taxonomy matching. (They reflect the kind of technical judgment that an experienced decision analyst might communicate to a new decision analyst).

Two examples (representing informally the coded form of this report) are:

> Generally consider using decision analysis on a single, non-recurring problem only if the "stakes" are more than a hundred thousand dollars, if the options are clearly visualized, and if the decision maker has more than usual difficulty in deciding among them.
>
> Use the Delphi method for eliciting group probabilities only if there is a high degree of disparity in the status of group members and if the sources of information available to them are rather similar.

A U.S. decision on whether to export high-technology items to the Soviet Bloc is analyzed by using the taxonomic matching framework. Other illustrative material is also used throughout the report.

In addition to direct use of this "universal" situation taxonomy, the notion of "specific" situation taxonomies, which refer to specific fields such as naval tactics, is introduced. Each specific taxonomy can be more or less loosely associated with the universal situation taxonomy and hence matched to analytic options. The use of a specific taxonomy is illustrated in a characterization of government-versus-business decision situations.

At the current state of development, the situation taxonomy is too complex to be applied routinely in unfolding decision situations. The idea of using a procedure for progressively applying the taxonomy so that it will operate like a succession of progressively finer screens is presented.

Further developments suggested include: developing "filtering" decision rules (possibly for implementation on an interactive computer) that permit sequential (and economical) elicitation of situation characteristics, refining the taxonomy matching for selected analytic choices, and developing parochial taxonomies and matchings for selected fields (e.g., contingency planning for naval tactics).

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PREFACE

The present paper is a technical report on a study conducted over a two-year period, 1974-1976. The study represents a continuing task within the decision analysis research program sponsored by Dr. Martin A. Tolcott, Engineering Psychology Programs, Office of Naval Research.

The Decisions and Designs, Incorporated (DDI) project team consisted of Rex V. Brown, the principal investigator, and Jacob W. Ulvila, under the general direction of Cameron R. Peterson, DDI Technical Director. The report was edited by Michael L. Hays, DDI Publications Manager.

Since this project is visualized as a tentative first step in a major undertaking, at its grandest, a codification of the art of decision analysis, we would very much appreciate any comments or suggestions which may help produce something like a definitive framework for ourselves and others to work with. If responses are encouraging enough, this material may be adapted at some stage for general publication.

1.0 INTRODUCTION

Decision makers and analysts who are in a position to recommend the use of decision analysis are faced with problems of determining what type of analysis, if any, to apply to a given decision situation. Currently, the decision maker or analyst must rely upon his own experience and must make an implicit, case-by-case judgment of the appropriate analytic approach for each decision situation. This report is an initial attempt to improve this process by providing a codification of the combined judgments of experienced decision analysts.

1.1 Object and Background

Decision analysis might be defined as "a technology of making up your mind." Central to this technology is the argument that, given a set of reasonable behavior assumptions, any person's optimal decision can be unambiguously determined from quantified measures of his judgments, attitudes, and perceptions, by maximizing his subjective expected utility. This technology has enjoyed substantial vogue in the literature of management science over the past decade.[1] As with most new technologies, however, the rate at which decision analysis has been applied in practice has been much slower than the rate at which its logical underpinnings have been developed. A reason for this lag is the lack of guidance that exists for identifying the most appropriate decision-analytic option to be used in a given situation.

The operational military commander or other decision maker has available to him, in principle, a moderately well developed array of decision-making aids based on decision analytic theory.[2] However, it is by no means always readily apparent to him or, indeed, to his technical advisors when and where he can most advantageously use these tools and how. In theory, these tools can be applied to an almost indefinitely variable degree, to any situation involving choice or inference.

The broad purpose of this project, then, is to guide the decision maker and, to a lesser degree, his technical

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[1] See, for instance, Raiffa (1968), Schalifer (1969), and Brown, Kahr, and Peterson (1974); and Handbook for Decision Analysis (1973).

[2] See, for example, Section 4 of Brown *et al*. (1974).

staff, in determining the appropriate use of decision-analytic tools. This paper is an attempt to produce some illustrative practical guidelines on the use of decision analysis. More importantly, it is an attempt to facilitate the advancement of the state-of-the-art of decision analysis by proposing a framework in which more definitive guidelines can be developed. It takes into account earlier, less extensive, attempts to classify or relate situations and analytic approaches.[3]

1.2 Terms of Reference

The main objective of this paper is to encourage and facilitate the codification of the current state-of-the-art of applied decision analysis. In order to meet this objective, this paper attempts to suggest a convenient taxonomy to classify a particular decision situation and a taxonomy of analytical options for addressing those situations, together with such guidance as can be given for an appropriate matching of the two.

Because an attempt to classify completely every conceivable decision-analytic option and every possible decision situation is an unmanageable task (with thousands of taxonomic characteristics for both analytic options and situations), the focus of this study is necessarily restricted. For now, we have chosen to restrict our main attention to those relatively few major dimensions which appear to be sufficient to characterize the important class of matching generalizations that are useful from the standpoint of a decision maker; only secondary consideration is given to developing guidelines for a decision analyst.

This restriction affects both the analytic taxonomy and the situation taxonomy. The scope of the analytic taxonomy is reduced because serious attention is devoted to the dozens of analytic options that are of interest to the decision maker rather than to the thousands of analytic options that are of interest to the analyst. The content of situation taxonomy is affected because the most appropriate characterization of a decision situation for specifying the correct options for the decision maker may differ from that appropriate for specifying the correct options for the analyst. For example, the fact that the decision situation calls for

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[3]For example, by Howard (1968), Howard _et al_. (1975 and 1976), MacCrimmon and Taylor (1973), Payne _et al_. (1974), and Von Winterfeldt (1975).

formal documentation of the reasons behind a choice may be very relevant to deciding whether or not to use decision analysis at all (a decision maker's option) but almost irrelevant to whether simulation or backwards induction be used in the conduct of the decision analysis (an analyst's option).

Primary attention is also restricted to providing universal situation characterizations that allow matching rules to be developed for decision situations in general rather than for a particular class of decision situations, such as those faced by a businessman or those faced by a Navy task force commander. This restriction affects the content of the situation taxonomy. In particular, the situation taxonomy contains situation characterizations that facilitate matching analytic options and situations, rather than ones that make it easy for a decision maker to classify a situation. Ultimately, to gain the maximum usefulness from the universal taxonomy, it will be necessary to develop taxonomies that enable situations to be more easily classified. This task is very large because decision makers in different fields, such as business or Navy tactics, tend to classify decision situations in different ways, with the result that a specialized taxonomy may be needed for each field. For example, a businessman may classify decision situations as investment decision situations, marketing decision situations, and so forth. A Navy task force commander, on the other hand, may classify decisions as crisis decisions or wartime decisions. Thus, the specific taxonomy that will serve to relate the decision maker's preferred method of classifying situations to the method used in the universal taxonomy will be different for the businessman and for the task force commander. The development of the specific taxonomies, however, is beyond the scope of the present paper.

The present paper develops a set of matching generalizations in a universal taxonomy and illustrates these generalizations in the context of an actual decision situation, a determination of what level of embargo on the role of computers to the Soviet Bloc should be favored by the U.S. government. In addition, the concept of a specific taxonomy is notionally illustrated in the context of a Navy task force commander's decision.

1.3 Research Approach

In constructing a taxonomy of decision-making situations, it is natural to inquire whether principles exist for the construction of taxonomies in general. The most widespread use of taxonomic procedures has been in the biological sciences, and much has been written on appropriate ways to

produce classification systems.[4] However, most of the stress in these writings is on the construction of automatic classification procedures. With these procedures, a dissimilarity measure is defined for pairs of objects that are to be classified, and then a clustering method is used to create classes. We do not feel that it is feasible to create such automatic classification procedures for decision-making situations, at least not at this early stage in our approach to the problem, since the similarity or dissimilarity between two decision-making situations is a matter of direct judgment. This similarity, at least at present, is unlikely to be derivable from a numerical formula. Other areas of study have used classification schemes, but there do not appear to be any principles in the literature for the construction of taxonomies that we can apply directly to decision-making situations.

The logic underlying the taxonomic matching of analytic options to situations is based upon the idea of maximizing the value of the decision analysis performed with due allowance for its cost. The formal principles of this idea,[5] are as yet cumbersome to apply in practice. Accordingly, the approach taken in this paper is rather informal, though implicitly it should be consistent with those principles.

The essential research approach used here was to examine the state-of-the-art as perceived by the authors and others and seek to codify the implicit taxonomic matching it represents. The illustrative methodological generalizations used were derived from the wide range of practical experience of analysts at Decision and Designs, Inc. In particular, the generalizations represent the judgments of two analysts (Rex V. Brown and Cameron R. Peterson), both of whom have actively applied decision analysis to a wide range of government and industry problems over the last eight years.

In addition, the situation taxonomy was checked and amplified by examining a large number of practical Naval and other decision situations. Experienced judgment was used to identify and prioritize their important distinguishing characteristics. Similarly, experienced judgment was applied to the classification of analytic options with a view toward making matching generalizations.

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[4]See, for example, Sokal and Sneath (1963) or Jardine and Sibson (1971).

[5]Watson and Brown (1975/1).

2.0 A TAXONOMIC FRAMEWORK

In this study, an attempt is made to suggest a taxonomic framework that provides the terms for codifying the state-of-the-art of decision analysis. These terms provide a language for expressing "matching generalizations," which identify the appropriate analytic alternatives in any particular situation. This language has three main components.

The first component is a "situation taxonomy," which classifies a situation in terms relevant for choosing analytic alternatives. Representative dimensions of the situation taxonomy include: the stakes involved in a decision, the reaction time available, and the clarity with which options, probable consequences, and values are perceived. The complete set of these dimensions define a "situation space" in which a situation can be unambiguously located. The set of situation dimensions is summarized in Appendix A.

The second component is an "analysis taxonomy," which locates decision-analytic choices in an "analytic-option space." Representative dimensions of the analytic taxonomy include: how much decision analysis is undertaken; what role is assigned to it; what model structure is used; and what kind of probability assessment or consequence evaluation is applied. A summary of the dimensions of the analytic taxonomy is presented in Appendix B.

The third component is a "performance measure taxonomy," (Appendix C) which allows matching situations and analytic alternatives. The state-of-the-art of applied decision analysis can be thought of in terms of mapping one space onto another, that is, matching a situation with an analytic alternative (see Appendix F). The validation of such a mapping requires either implicit or explicit mediation of the performance measure taxonomy since its dimensions can be associated with situations as priorities and with analysis alternatives as properties. That is, although analytic options can always be matched to situations, the matchings cannot be justified or validated except by using the performance measure taxonomy. Representative dimensions of the performance measure taxonomy include: enhanced logical reasoning, lowered cost, and facilitated communication.

2.1 Situation Taxonomy

The situation taxonomy contains dimensions for classifying decision situations in a manner that facilitates identifying the appropriate amount of decision analysis and the appropriate decision-analytic choices for a given situation. This taxonomy includes only those situation distinctions, a

subset of all possible distinctions, impacting on those performance measures (see Section 2.3) that are important for determining the appropriate amount or type of decision analysis.

Table 2-1 contains a summary of questions (dimensions) in the situation taxonomy. Appendix A presents a detailed description of the taxonomic questions and possible responses (values) which between them define the situation characteristics.

Each situation characteristic is numerically coded for easy reference; thus, S112 refers to the question, "Expected Number of Occurrences," and S1123 refers to the answer, "Expected Number of Occurrences = 2" (defined in Appendix A). The "S" is used to distinguish the situation characteristics from other taxonomies. The final digit of the code is always a specific response to the question indicated by the other digits.

The items of Table 2-1 enclosed in parentheses are questions that distinguish only the type of decision analysis, not the appropriate amount of decision analysis, to be performed. Thus, these should be ignored in a first pass at characterizing a situation.

2.2 Analytic Options

The analytic taxonomy, summarized in Table 2-2 and detailed in Appendix B, attempts to identify many, but not all, decision-analytic choices available to decision makers and analysts and to classify them in a manner that facilitates a matching of specific alternatives to a decision situation. Future references to the analytic options will be preceded by the letter "A." Analogously to the situation taxonomy, the first digits signify the choice to be made; the last digit in the code corresponds to a specific alternative. For instance, "comprehensive/partial analysis?" will be referenced as A22 and "comprehensive analysis" as A221.

As with the situation taxonomy, any particular analysis will, in general, be characterized by a number of choices.

2.3 Performance Measures

The following list of performance measures attempts to capture the dimensions sufficient to determine the amount and type of decision analysis to use. To the extent that the relative importance of these measures can be determined directly in a given situation, the situation taxonomy presented

1 Decision Substance	2 Decision Process
11 BASIC SITUATION	**21 REACTION TIME**
111 current/contingent choice	211 minutes
112 expected # of occurrences	212 hours
(113 operating/information act)	213 days
119 other basic situation	214 months
12 OPTIONS	**22 ANALYTIC PROCESSES**
(121 broad/narrow)	221 # of input sources
122 clear/fuzzy	222 analytic team
123 complexity of decision options	223 constraints on analytic method
124 radical/adaptive	224 documentation
125 static/dynamic	229 other
129 other options	
13 DECIDABILITY	**23 ORGANIZATIONAL PROCESSES**
131 difficulty of choice	(231 initiation)
132 unfamiliarity	232 responsibility
133 key considerations	(233 coordination)
134 other decidability	234 justification
	235 controversiality
	236 performance control
	237 rational-actor model
	238 risk attitude
14 STAKES	239 other organizational processes
141 resources committed	
142 cost swing	
143 value swing	
144 maximum option impact	**24 DECISION MAKER CHARACTERISTIC**
145 expected irrationality cost	
149 other stakes	241 role in organization
	242 personal characteristics
	249 other
15 OUTCOME VALUATION	
151 difficulty of net valuation	**25 RESOURCES AVAILABLE**
(152 # of value dimensions)	
(153 measurable value?)	251 computational facilities
(154 natural combinability of values)	252 staff
	253 decision analysis expert
(155 timing)	254 availability of decision maker
(156 difficulty of component valuation)	(255 availability of assessors)
159 other outcome uncertainty	256 dollars available
	259 other resources
16 OUTCOME UNCERTAINTY	**29 OTHER DECISION PROCESSES**
161 # of uncertainties	291 negotiation
162 determinability	
163 high/low uncertainty	
164 subsequent acts	
(165 type of evidence)	
166 hindsight monitoring	
169 other outcome uncertainty	
19 OTHER DECISION SUBSTANCE	

Table 2-1: SITUATION TAXONOMY – SUMMARY

1 USER'S OPTIONS

11 USE DECISION ANALYSIS AT ALL?

111 intuitive
112 decision analysis
119 other

12 DOLLAR AMOUNT OF ANALYSIS

121 low
122 medium
123 high

13 ROLE OF DECISION ANALYSIS

131 private/public aid
132 prescribed/optional
133 contingent/current analysis
134 optimization/display
135 communication

14 ORGANIZATION

141 analysis source
142 input source
143 "vest-pocket" relation to decision maker?

15 RESOURCES

151 use a decision analysis expert?
152 use a computer?

2 MODEL APPROACH OPTIONS

21 COMPLEXITY OF ANALYSIS

211 simple
212 moderately complex
213 very complex

22 COMPREHENSIVE/PARTIAL ANALYSIS

221 comprehensive
222 partial

23 APPROXIMATE ANALYSIS?

230 no
231 yes

3 INPUT STRUCTURE

31 UNCERTAINTY

311 explicit modeling
312 time horizon
313 subsequent acts
314 event sequency ordering
315 detail level
316 degree of grouping

32 VALUE

321 comprehensive?
322 decomposed?
323 partial list?
324 single index?
325 function?

33 SPECIAL FORMS

331 Markov
332 Pareto
333 linear programming

4 INPUT SPECIFICATION

41 DECISION OPTIONS

411 specificity of definition
419 other

42 EVENTS

421 scenarios
422 specific
429 other

43 VALUE CRITERIA

431 units
432 base
433 evaluation date(s) for time stream

44 INDIRECT ASSESSMENTS

441 conditioned assessment model?
442 Bayesian updating?
443 decomposed assessment model?
444 regression?
449 other

45 ELICITATION TECHNIQUE

451 for discrete probabilities
452 for continuous variables
453 for values
454 use group elicitation?

5 OUTPUT

51 SPECIFICATION

511 preferred decision
512 single value for each option
513 value distributions
519 other

52 DISPLAY FORMAT

521 graphic
522 computer
529 other

53 ANALYTIC DEVICES

531 use simulation
539 other analytic devices

6 MODEL MANAGEMENT

61 MODEL DYNAMICS

611 combining
612 pooling
613 sequential modeling
614 decision option scanning
615 input iteration

62 CONTINGENT ANALYSIS INPUT SEQUENCE

621 values
622 priors
623 likelihood
624 data

Table 2-2: ANALYTIC TAXONOMY – SUMMARY

above is unnecessary. However, because it is typically very difficult to determine this rating, performance measures must serve an intermediate purpose in matching analytic options to situations.

Table 2-3 contains a summary taxonomy of performance measures, and Appendix C presents a detailed description of each measure. In future references, the performance measure numbers will be preceded by the letter "P." For instance, "conceptual completeness" will be referenced as P111. By contrast to the situation and analysis taxonomies, specific values on the dimensions have not been coded as the final digit.

1 <u>Quality of Decision</u>

11 LOGIC OF CHOICE

- 111 conceptual completeness
- 112 effective disaggregation
- 113 sound predictions
- 114 good overall logic
- 115 scope
- 119 other

12 QUALITY OF INPUT

- 121 good data gathering
- 122 good management of staff/ expertise
- 123 posing meaningful questions
- 124 good overall input quality
- 129 other

2 <u>Time and Cost</u>

21 ELAPSED TIME

- 211 short elapsed modeling
- 212 fast input assignment
- 213 fast calculation
- 214 fast interpretation
- 215 short overall net elapsed time
- 219 other

22 COSTS

- 221 inexpensive analysis
- 222 inexpensive input assignment
- 223 inexpensive calculation
- 224 inexpensive overall
- 229 other

3 <u>Other Considerations</u>

31 ACTIVITY PRECEDING CHOICE PROCESSES

- 311 good environment monitoring
- 312 good decision identification
- 313 good option generation
- 314 good pre-analysis of anticipated decisions
- 319 other

32 ACTIVITY FOLLOWING CHOICE PROCESSES

- 321 good decision communication
- 322 good hindsight evaluation
- 323 effective implementation
- 329 other

33 ORGANIZATIONAL AND OTHER NON-"CHOICE SPECIFIC" IMPACTS

- 331 improved information
- 332 improved command, control, and communication
- 333 improved body of applied precepts
- 339 other

Table 2-3: PERFORMANCE MEASURES — SUMMARY

3.0 MATCHING HIGHLIGHTS

In Section 3.1, we shall generate matching hypotheses about the circumstances that justify the use of any decision analysis based on our applied experience. In doing so, we shall uncover and identify the relevant situation taxonomy that these generalizations imply. Throughout this effort, the emphasis is on ensuring that the generalizations address the proper situation taxonomic considerations rather than on ensuring that the specific generalizations are correct. It is certainly not argued that these generalizations are ready for adoption as they stand as tenets of recommended decision-analytic practice.

There is, in principle, a different situation taxonomy for every level of decision-analytic alternatives (despite a substantial amount of overlap). For example, to decide whether to use decision analysis at all requires characterizing a decision situation according to stakes, reaction time, and the like, whereas deciding whether to use the Delphi method for group elicitation requires such information as whether the informant group has heterogeneous status and homogeneous information.

It is not feasible to itemize exhaustively the union of all such special-purpose sets of characteristics, and it is even less feasible to generate a complete set of matching generalizations for all decision-analytic alternatives and their associated situation taxonomies. To attempt any kind of completeness is to attempt to codify the whole state-of-the-art of decision analysis.

Accordingly, since our aim is more modest, we shall explore only a limited set of matching generalizations that appear either important in their own right or are in some sense representative of a complete taxonomy. The primary motivation is to generate a useful, somewhat general-purpose situation taxonomy that suggests interesting, even provocative, selective generalizations about the state-of-the-art. This preliminary and partial treatment may provide a starting point for developing definitive situation taxonomies and matching generalizations. In Section 3.2, we extend the matching concept to the determination of the form of decision analysis to use.

3.1 <u>Amount of Decision Analysis</u>

In this section, we restrict attention to the most common and perhaps most critical analytic choice: how much

decision analysis, if any, to perform. This choice will be analyzed in two steps. First, decision analysis will be characterized in terms of the performance measures introduced in Section 2.3. Second, the analytic choice of how much decision analysis to perform will be related through performance measures to the situation taxonomy of Section 2.1.

Throughout this section, references to the situation taxonomy will be preceded by the letter "S" and references to the performance measure taxonomy will be preceded by the letter "P." These items are explained in detail in Appendices A and C respectively.

3.1.1 Performance characteristics of decision analysis - The validation of any of the matching generalizations in Sections 3.1.2, 3.2.1, 3.2.2, and 3.2.3 will be through the explicit or implicit mediating role of performance measures summarized in Section 2.3 above.

This section explains how, in general, decision analysis performs along the different performance measures. In all cases, the comparisons are between decision analysis and conventional decision-making practice as exemplified by intuitive or informal decision-making procedures. Decision analysis is not being compared with other quantitative approaches such as operations research or management science techniques although we recognize that these techniques are often appropriate. In all cases, the statements presented are broad generalizations and there are exceptions. The generalizations represent highly personal judgments of the authors, but they are grounded in substantial experience.

The following performance measure generalizations are presented in the order in which the measures appear in Table 2-3, "Performance Measure Summary," rather than in order of importance.

Decision analysis generally performs well in the first performance area, quality of decision (P1).[1] That is, to the extent that this performance measure is important, a large amount of decision analysis is indicated. Under the logic of choice category (P11), decision analysis performs well on most sub-categories. In particular, use of more decision analysis generally leads to: more effective disaggregation of the problem into manageable sub-problems (P112), sounder predictions based upon the available data

[1]Parenthetical references are to the performance measure taxonomy detailed in Appendix C and summarized in Table 3-2.

(P113), and better overall logic (P114). However, it is not clear whether more decision analysis leads to a more conceptually complete consideration (P111). On one hand, using decision analysis tends to increase understanding, but, on the other hand, using decision analysis can lead to serious omissions. Thus, on balance, the use of more decision analysis leads to better overall logic (P114).

In the quality of input category (P12), decision analysis performs well on all sub-categories. In particular, the use of more decision analysis will, frequently, promote:

- Better data gathering (P121);
- Better management of staff and expertise (P122); and
- More meaningful questions (P123);

all of which result in better overall input quality (P124).

While the quality of decision (P1) usually increases with an increased use of decision analysis, the time and costs involved (P2) also increase.

First, using decision analysis will generally increase elapsed time (P21) on a first pass, which includes slower first-pass modeling time (P2111), slower first-pass input assignment (P2121), and slower first-pass calculation (P2131). It is not clear whether or not the first-pass interpretation speed (P2141) will be affected by the amount of decision analysis. Thus, overall first-pass elapsed time (P2151) will be longer.

Additional passes of the analysis will, however, generally be faster when decision analysis is used. While it is not clear that this is the case with the elapsed modeling time (P2112), it is the case with input assignment (P2122), calculation (P2132), and interpretation (P2142). Thus, overall time for additional passes (P2152) is reduced. The net for the total overall elapsed time (P2153), including both first and additional passes, is generally greater when decision analysis is used.

In the cost category (P22), more decision analysis always raises the cost of the decision analysis. Greater analytic cost occurs in all of the sub-categories: analysis cost (P221), input assignment cost (P222), calculation cost (P223), and overall cost (224). It occurs for both the first pass and additional passes. It should be emphasized that cost as used in this context refers to the cost of the decision analytic effort, not to gains or costs that might accrue to decision

outcomes from having applied more or less decision analysis to the problem. The trade-off of analytic costs (how much analysis) with the possible impact of that analysis is one of the uses of the proposed taxonomy.

In the third area, other considerations (P3), the effects of decision analysis cannot be generalized for most sub-categories. Using more decision analysis does not have a clearly generalizable effect on environment monitoring (P311), decision identification (P312), option generation (P313), pre-analysis of anticipated decisions (P314), implementation (P323), information processing (P331), or command, control, and communication (P332). However, use of decision analysis will generally improve decision communication (P321), hindsight evaluation (P322), and the body of applied precepts (P333).

The amount of decision analysis indicated in a situation can be determined by a direct assessment of the relative importance of the performance measure. That is, to the extent that the performance measures favoring decision analysis are more important than those not favoring decision analysis, more decision analysis is indicated. However, since it is typically difficult to determine the relative importance of the performance measures directly, it is usually more convenient to use the following situation taxonomy to determine the proper amount of decision analysis.

3.1.2 <u>Situations favoring the use of decision analysis</u>- The above section explained that a situation characterization in terms of performance measures is sufficient to determine the appropriate amount of decision analysis. However, because this characterization is often difficult to obtain, the situation taxonomy presented in Section 2.1 was developed. This taxonomy is a more natural way to classify situations, but it is not directly relatable to the appropriate amount of decision analysis.[2]

This section summarizes the most important aspects of the means by which situations can be related to the appropriate amount of decision analysis through the performance measures. Appendix D contains a more detailed matching of how much decision analysis to use in a situation which addresses all situation dimensions shown in Table 2-1.[3] Unless otherwise

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[2]The matching task is conceptually analogous to the formulation of a regression problem. This analogy is presented in Appendix F.

[3]Situation dimensions are detailed in Appendix A.

noted, situations that support the use of decision analysis also support the use of more decision analysis. (Whenever a statement is made that a certain situation characteristic supports the use of decision analysis, it implies that the more that an actual situation exhibits the situational characteristic, the greater the quantity of decision analysis that is supported.) All statements are guidelines and need to be viewed as a whole rather than in isolation. Combined effects of several dimensions may cause decision analysis to be favored where no single categorization is sufficient to make that indication.

As shown in Table 3-1, a large amount of decision analysis is most strongly recommended in a situation with:

- Clear options (S1221)[4]
- A difficult choice (S1312)
- A choice as the key consideration (S1334)
- A maximum option impact greater than \$10 million (S1444)
- Several substantive and preference sources (S2215)
- Required pre- and post-decision justifications (S2343)
- A decision maker who is familiar with decision analysis (S24213).

In addition, a large amount of decision analysis is supported, but less strongly, by a situation with:

- A current choice (S111)
- A recurring choice (S1124)
- A difficult valuation (S1512)
- Indeterminable uncertainties (S1621)
- Months of reaction time (S214)
- Organizational processes resembling a rational-actor model (S2372)
- Availability of many computational facilities (S2512)
- A strong staff (S2522)
- A high degree of decision maker availability (S2542)
- A high degree of dollar availability (S2563).

An example illustrating the use of these rules is presented in Section 4.1.1 below.

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[4]Situation dimensions are detailed in Appendix A.

	SITUATION CHARACTERISTICS			Amount of Decision Analysis: None	Lo - < $15K	Med - $15K-$50K	Hi -> $50K
Decision Substance	Basic Situation	S1111	Current Choice				X
		S1124	More than two expected # of Occurences				X
	Options	S1221	Clear Options				X
	Decid-ability	S1312	Difficult Choice				X
		S1334	Key Consideration Choice				X
	Stakes	S1441	Maximum Option Impact < $100K	X			
		S1442	Maximum Option Impact $100K-$5M		X		
		S1443	Maximum Option Impact $5M-$10M			X	
		S1444	Maximum Option Impact > $10M				X
	Outcome Valuation	S1512	Very Difficult Net Valuation				X
	Outcome Uncertainty	S1621	Indeterminable Uncertainties				X
Decision Processes	Reaction Time	S214	Months of Reaction Time				X
	Analytic Process	S2215	Several Input Sources for Both Preferences and Substantive Inputs				X
	Organiza-tional Processes	2343	Both Pre and Post Justification				X
		2372	Rational Actor Model is Good Approx.				X
	Decision Maker Character-istics	S24213	D. M. Has Much Familiarity with Decision Analysis				X
	Resources Available	S2512	Many Computational Facilities Available				X
		S2522	Strong Staff Available				X
		S2542	Much Decision Maker Availability				X
		S2563	Greater than $50,000 Available				X

☐ Indicates the key situation characteristics

Table 3-1: MATCHING HIGHLIGHTS – AMOUNT OF DECISION ANALYSIS

The following paragraphs summarize the reasoning behind the primary situation characterizations that support the use of decision analysis.

Decision analysis can improve conceptual completeness (P111) most when the choice options are clearly specified (S1221).

Decision analysis can provide the greatest improvement in the decision quality (P1) for difficult choices (S1312). When choice is difficult, informal decision processes leave much room for improvement, which can be filled by using decision analysis.

Decision analysis can generally improve choice logic (P11). Thus, decision analysis is indicated in situations in which choice is the key consideration (S1334).

The stakes involved in the decision (S14) are the single most important situation classification for determining the appropriate amount of decision analysis. In general, the cost of the analysis (P22) becomes less important as the stakes increase. Thus, decision analysis is indicated in high stakes situations. As a rough rule of thumb, we suggest that the maximum option impact, the dollar equivalent difference in outcome attributable to the choice of the best decision over the worst reasonable decision, should be on the order of $100,000 (S1442) to justify any decision analysis. Of course, decision analysis is more strongly indicated if the maximum option impact is greater than this threshold.

Conventional, intuitive decision practice has difficulty organizing input from a variety of sources. Decision analysis, however, provides a method for organizing a diverse set of inputs. In particular, decision analysis can improve the quality of both input (P12) and choice logic (P11) when multiple input sources (S2215) exist. Input quality is especially improved through the effective management of staff and expertise (P122), and choice logic is especially improved through effective disaggregation of the decision problem (P112).

Decision analysis can provide a vehicle for good decision communication (P321), which is required in situations in which decision justification is needed (S2343).

In a situation in which the decision maker is familiar with decision analysis (S24213), the analysis can provide its greatest benefits, especially the effective implementation of a decision (P323), the effective management of staff expertise (P122), and good overall decision logic (P114).

Secondary considerations that support the use of decision analysis are as follows:

Current choice (S1111) favors the use of decision analysis because it is certain that the analysis could be used. Since decision analysis is a tool to aid in decision making, its value as an aid is reduced in contingent situations (S1112) in which it is uncertain that the decision will ever occur.

A decision that is expected to recur (S1124) supports the use of decision analysis because the cost (P22) per analysis is reduced. The amount of advantage gained by recurrence, of course, depends upon both the expected frequency of recurrence and the similarity of the recurring situations because the similarity determines the amount of modification needed before the analysis can be used again. The expected number of occurrences is, in general, closely related to the current/contingent question (S111), explained above, and the two dimensions should be considered simultaneously. For instance, a current decision that will occur only once should be considered the same as a contingent decision that has a 50% chance of occurring twice. Both of these situations have an expected occurrence rate of one.

Decision analysis can improve choice logic (P11) in situations in which valuation is difficult (S1512).

Decision analysis can improve choice logic (P11) in situations in which uncertainties are indeterminable (S1621), in the sense that it is difficult to determine what the appropriate probability distribution should be (regardless of whether it has a large or small dispersion).

More time is required to perform a decision analysis than to use informal, intuitive decision-making techniques. Thus, situations with long reaction time (S214) support the use of decision analysis.

Since decision analysis assumes a rational-actor model, a situation that is a good approximation of the model (S2372) supports the use of decision analysis.

Good computational facilities tend, in general, to reduce the cost of analysis (P221). Thus, decision analysis is supported where good computation facilities exist (S2512).

A strong staff (S2522) is most likely to perform a decision analysis correctly and thus improve the overall logic of the choice (P114).

If a decision maker is unavailable during the analysis time, the improvement in choice logic (P11) and input quality (P12) provided by decision analysis is reduced. Thus, decision analysis is supported when the decision maker is available (S2542).

When a large resource is available for an analysis (S2563), the cost of the analysis becomes unimportant. Thus, the use of decision analysis is supported by a large available resource.

This section has highlighted the key situation dimensions that support the use of decision analysis. A more thorough examination of the relationship between the situation taxonomy and the amount of indicated decision analysis is presented in Appendix D.

3.2 Examples of Type of Analysis

In this section, the matching concept of Section 3.1 is extended to the determination of the form of decision analysis to use in a given situation. This matching is summarized in Table 3-2. This section will highlight the summary by presenting three examples:

- Situations favoring the use of a contingent choice analysis,
- Situations favoring the use of a computer to perform the analysis, and
- Situations favoring the use of the Delphi assessment technique.

Appendix E contains a detailed description of all of the matching generalizations shown in Table 3-2. A case illustration of this part of the taxonomy matching in use appears in Section 4.1.2.

3.2.1 Contingent analysis (A1331)[5] (analysis in advance of a decision that is expected to arise in the future) - Performance characteristics: A contingent choice analysis requires a large amount of time initially (P2151).[6]

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[5] Analytic options are described in Appendix B.

[6] Performance measures are described in Appendix C.

Type of analysis	S1111 CURRENT CHOICE	S1112 CONTINGENT CHOICE	S1124 MORE THAN TWO EXPECTED # OF OCCURRENCES	S1221 CLEAR OPTIONS	S1222 FUZZY OPTIONS	S1331 EASY CHOICE	S1312 DIFFICULT CHOICE	S1333 KEY CONSIDERATION: INFERENCE	S1334 KEY CONSIDERATION: CHOICE	S1442 MAXIMUM OPTION IMPACT MODEST	S1444 MAXIMUM OPTION IMPACT HIGH	S1510 EASY NET VALUATION	S1512 VERY DIFFICULT NET VALUATION		S1551 EARLY TIMING	S1552 LATE TIMING	S1621 INDETERMINABLE UNCERTAINTIES	S1623 HIGHLY DETERMINABLE UNCERTAINTIES	S1643 IMPORTANT SUBSEQUENT ACTS	S211 MINUTES OF REACTION TIME	S214 MONTHS OF REACTION TIME	S2213 SEVERAL PREFERENCE SOURCES	S2214 SEVERAL SUBSTANTIVE SOURCES	S2343 BOTH PRE AND POST JUSTIFICATION	S2352 VERY CONTROVERSIAL DECISION	S2372 RATIONAL ACTOR MODEL IS GOOD APPROX.	S24213 DECISION MAKER HAS MUCH FAMILIARITY WITH DECISION ANALYSIS	S2512 POWERFUL COMPUTER AVAILABLE	S2520 NO STAFF AVAILABLE	S2522 STRONG STAFF AVAILABLE	S2540 DECISION MAKER NOT AVAILABLE	S2542 DECISION MAKER VERY AVAILABLE	S2551 LOW ASSESSOR AVAILABILITY	S2552 HIGH ASSESSOR AVAILABILITY	S2561 LESS THAN $15,000 AVAILABLE	S2563 GREATER THAN $50,000 AVAILABLE	OTHER
	DECISION SUBSTANCE: BASIC SITUATION			OPTIONS		DECID ABILITY				STAKES		OUTCOME VALUATION					OUTCOME UNCERTAINTY			DECISION PROCESS: REACTION TIME		ANALYTIC PROCESSES		ORGANIZATIONAL PROCESSES			DECISION MAKER CHARACTERISTICS	RESOURCES AVAILABLE									OTHER
A123 LARGE DOLLAR AMOUNT OF DECISION ANALYSIS	X		X	⊠			⊠		⊠		⊠		X				X				X	X	X	⊠		X	⊠	X		X		X				X	
A1331 CONTINGENT CHOICE		⊠	⊠	X							⊠									⊠		X															PREDICTABLE ANALYSIS
A1341 OPTIMIZATION																				X																	COMPREHENSIVE ANALYSIS (A221)
A1521 USE A COMPUTER			⊠								⊠										X							⊠		X							CLEAR, COMPLEX STRUCTURE (A213), HIGH INPUT ITERATION (A61533)
A213 VERY COMPLEX ANALYSIS							X				X					X			X		X	X	X	X	X		X	X		⊠	X			X		X	NO JUSTIFICATION NEEDED (S2340)
A2221 PARTIAL ANALYSIS--INFERENCE ONLY					X			X		X			X				X																				
A231 APPROXIMATE ANALYSIS						X				X																				X							MANUAL COMPUTATION
A3121 SHORT TIME HORIZON													X	⊠				X															X			X	LOW UNCERTAINTY (S1631) LOW COMPLEXITY (A211)
A3132 SUBSEQUENT ACTS AS EVENTS																			X																		INFORMATION & SUBSEQUENT ANALYSIS DIFFICULT TO MODEL
A3221 DECOMPOSE VALUES										X	X		X								X	X			X			X		X				X			NATURE OF VALUE
A32411 ADJUSTED VALUE INDEX																								X	X												OPTIMIZING MODE (A1341)
A32511 LINEAR VALUE FUNCTION																								X					X				X				
A3311 MARKOV MODEL								X				X						X																			SPECIAL STRUCTURE
A3321 PARETO MODEL																																					NEGOTIATION (S291)
A3331 LINEAR PROGRAMMING MODEL				⊠								X																X		X	X						LARGE OPTION VECTOR (S1236) CERTAIN (S1630), LINEAR, STRUCTURED
A4322 FLOATING VALUE BASE										X		⊠																		X							SUBTLE TO COMMUNICATE (S2340)
A4413 MANY CONDITIONING TIERS								X		X	X						⊠				X		X					X		X							EACH TIER ACCOUNTS FOR 10%-20% OF TOTAL VARIANCE
A4421 BAYESIAN PROBABILITY MODEL								X																						X							SPECIAL PERCEPTUAL STRUCTURE
A4531 REFERENCE GAMBLE ELICITATION																								X						⊠				⊠			
A4541 DELPHI ASSESSMENT																							⊠														STATUS HETEROGENEOUS, DATA HOMOGENEOUS
A53111 SIMULATION											X																										COMPLEX STRUCTURE (A213), CONDITIONED ASSESSMENT (A4413)
A531111 STEP-THROUGH SIMULATION																X	X							X						⊠				X			

X Indicates a situation/analytic match ☐ Indicates a key matching characteristic

*Taxonomic dimensions relate to application presented in Section 4.1.2.

Table 3-2: MATCHING SUMMARY – TYPE OF ANALYSIS

However, it provides a fast response on subsequent uses (P2152). In addition, in a situation characterized by a short reaction time (S211)[7], performing a contingency analysis in advance can improve choice logic (P11), input quality (P12), and control (P332).

Situations favoring contingent analysis - The most important situation considerations for determining whether to perform a contingent analysis include the number of occurrences (S112), the stakes (S144), and the reaction time (S21).

In general, contingent choice analysis is indicated in situations in which its cost (P22) is justified by either a large number of occurrences (S1124) or by large stakes (S1444). As a rule of thumb, a contingent analysis should not be performed unless the expected number of occurrences is at least one (P1122) (for example, occurring once with certainty or occurring twice with a 50% probability). It is also necessary to consider the similarity as well as the number of the occurrences. The more similar the situations are, the more the contingent analysis is justified. (As a rule of thumb, three similar recurrences are roughly equivalent to a single identical recurrence.) For a good pre-analysis (P314), it is critically important that the actual decision is predictable, that is, involves the same considerations that are modelled.

As a guideline, the expected option impact over a number of occurrences should exceed $10 million (S1444) to justify the cost of a contingent analysis. Brown et al. (1975) present an illustration of this guideline in a Navy task force commander's decision situation.

In a situation with a short reaction time (S211), a pre-analysis of contingencies can improve decision quality (P1) by providing a logical framework that considers all available data.

In addition, a contingent analysis is supported, but less strongly, by a situation with clear options (S1221) and several value sources (S2213). Clear options (S1221) allow a contingent analysis to provide a good pre-analysis of the anticipated decision (P314). Clear options also enhance predictability (see above). Contingent choice analyses can improve command, control, and communication (P332) in situations that require several value sources to be considered (S2213).

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[7]Situation dimensions are described in Appendix A.

3.2.2 Use of computer (A1521) - Performance characteristics: A computerized analysis is generally time-consuming and costly to set up (P2131 and P2231) but is fast and inexpensive to run (P2132 and P2232). However, when an analysis is complex, a computer may not increase the initial time or cost.

Situations favoring the use of a computer include a recurring situation (S1124) or a situation with large stakes (S1444). Since a computer offers faster and less expensive performance on subsequent passes, its use is supported by a large expected number of occurrences (S1124). Large stakes argue for the use of a computer for two reasons. First, large stakes justify the large costs needed for a computerized analysis. Second, a situation with large stakes generally involves a complex analysis. In this case, a computerized analysis may not be more expensive than a manual analysis.

The following situations support the use of a computer, but less strongly than those mentioned above.

A computer analysis requires at least several days of anticipatory reaction time (S213). However, since a computerized analysis runs quickly, only minutes of execution reaction time (S211) are needed.

Some staff support (S2521) is needed to program a computerized analysis.

The costs (P22) and time (P21) of a computerized analysis are not significantly worse than the alternative of a non-computerized analysis if the situation has clear, complex options (S1221 and S1236); many determinable uncertainties (S1613 and S1623); and many measurable values (S1523 and S1532).

A computer is also recommended in conjunction with a complex analysis (A213) and with simulation (A5311).

3.2.3 The Delphi Technique (A45411) (a group elicitation technique for probabilities) - Performance characteristics: The Delphi technique involves pooling opinions of several probability assessors while allowing only limited interaction among them.

Situations favoring the use of the Delphi Technique include only those with several uncertainty sources (S2214).

The Delphi technique limits interaction among assessors and provides the assessors with anonymity. Thus, the Delphi technique removes inhibition and allows better use of staff expertise (P122) in cases in which the status of the assessors is heterogeneous. However, if data is heterogeneous, then the Delphi technique reduces input quality (P12) by inhibiting useful interactions. (See Fischer [1975] for a further evaluation of the Delphi technique.)

4.0 MODE OF USE

The primary objective of the taxonomy of decision situations presented above is to provide the decision analysis user with a convenient device for recognizing promising situations in which to use decision analysis, and to guide him in making the kinds of analytic choices illustrated in Sections 3.1 and 3.2. At the current state of development, the situation taxonomy, though incomplete, is too complex to be applied routinely in unfolding decision situations.

What is ultimately needed is a procedure for progressively applying the taxonomy so that it will operate like a succession of progressively finer screens. The answers to a few routinely applied questions, perhaps related to the size of the stakes involved, the time available to make a decision, the clarity of the choices, and the complexity of the outcomes, will signal which situations should be seriously considered for decision analysis. For those, a second level of more sharply focused questions will be used to make a definitive decision on whether to use decision analysis and, if so, what role the analysis will serve. After resolving these issues, even more sharply focused questions will be used to determine the detailed planning of the analysis. The screening would continue until the exact analytic options are identified, or until informal technical judgment is sufficient to designate the type of analysis.

4.1 Application of Universal Taxonomy

As explained in Section 1.2, this paper has developed a universal situation taxonomy to aid in matching decision-analytic options to decision situations. Section 4.1.1 below illustrates how the universal taxonomy should be applied to a decision situation in order to determine the appropriate amount of decision analysis, and Section 4.1.2 illustrates the use of the universal taxonomy in choosing the type of analysis for the same situation.

4.1.1 Amount of decision analysis to use on export control decision - In the summer of 1973, a senior staff member of the President's Council of International Economic Policy (CIEP) had to make a recommendation to the President on the level of embargo for computers sold to the Soviet Bloc. If approved by the President, in consultation with the Departments of State and Defense, this recommendation would provide the basis for the U.S. position on COCOM embargo policy. COCOM, an international coordinating committee representing the major western powers and Japan, is charged

with controlling the export of computers and other strategic items to communist countries. The essential decision by COCOM was to specify where, in terms of computing power, to set the "easy access line" for computers.

Six weeks before his recommendation was due, the CIEP staffer was faced with a very large array of reports from experts on the complex issues involved in the decision. These issues included the impact of the decision on military threat, U.S. computer sales, the attitude of COCOM allies, and other economic and political considerations. Although the staffer had some sense of where the "easy access line" should be set, he felt uneasy about his ability to properly digest and interpret the complex mass of data available to him within the short time available.

The first question, then, was how much, if any, decision analysis the staffer should have done, and, secondly, what specific form the decision analysis should have taken.

Table 4-1 indicates how the matching highlights shown on Table 3-1 might be used, informally, to conclude that a substantial amount of decision analysis should be used. It can be seen that all but three of the seventeen situation characteristics favoring a large amount of decision analysis are present in this case, including all but one of seven key characteristics.

Specifically, proceeding from left to right, we see that the choice was a current one, and that the decision situation is expected to recur (the issue is expected to come up for re-examination every two years or so). The options are somewhat clear, in the sense that the theoretically rich and complex option space could be reduced to six specific alternatives without gross over-simplification. The choice was, however, not particularly difficult in that the decision maker was rather sure that the right choice lay between three of the six options. The decision maker saw his key problem as choosing from among perceived options (rather than making predictions or determining what the options are, for instance). All measures of stakes were very high, the maximum option impact was on the order of hundreds of millions of Federal budget dollars. The net valuation of possible outcomes was very difficult (trade-offs of economic, political and military considerations were required), but there was no unusually great indeterminability of uncertainties. The reaction time was on the order of a couple of months. There

Situation Characteristics			Amount of Decision Analysis: None	Lo- $15k	Med-$15k-$50k	Hi- $50k	Export Control Characterization
Decision Substance	Basic Situation	S1111 Current Choice				X	+
		S1124 More than 2 expected # of Occurrences				X	+
	Options	S1221 Clear Options				X	+
	Decide-ability	S1312 Difficult Choice				X	-
		S1334 Key Consideration Choice				X	+
	Stakes	S1441 Maximum Option Impact < $100K	X				
		S1442 Maximum Option Impact $100K-$5M		X			
		S1443 Maximum Option Impact $5M-$10M			X		
		S1444 Maximum Option Impact > $10M				X	+
	Outcome Valuation	S1512 Very Difficult Net Valuation				X	+
	Outcome Uncertainty	S1621 Indeterminable Uncertainties				X	-
Decision Process	Reaction Time	S214 Month of Reaction Time				X	+
	Analytic Processes	S2215 Several Input Sources for Both Preferences and Substantive Inputs				X	+
	Organiza-tional Processes	2343 Both Pre and Post Justification				X	+
		2372 Rational Actor Model is Good Approx.				X	+
	Decision Maker Character-Istics	S24213 D. M. Has Much Familiarity with Decision Analysis				X	+
	Resources Available	S2512 Many Computational Facilities Available				X	+
		S2522 Strong Staff Available				X	+
		S2542 Much Decision Maker Availability				X	+
		S2563 Greater than $50,000 Available				X	-

X (boxed) Indicates the key situation characteristics

+ Indicates characteristic is present
- Indicates characteristic is not present

Table 4-1: EXPORT CONTROL EXAMPLE – AMOUNT OF DECISION ANALYSIS

were several different sources of input for the various types of uncertainty and prediction, all of which were different from the sources of value judgment. The decision required justification in a formal report to the President and in verbal presentations to representatives of industry and government agencies both before and after the decision was to be made. The decision processes of government for this decision are reasonably "rational" (in that reasoned argument is a large part of the persuasion process). The decision maker was highly familiar with decision analysis (having taught the subject at a major univeristy). Computational facilities and staff skills were more than adequate. The decision maker was able to spend large amounts of time participating in the analysis on a regular basis. However, the budget available was quite modest, on the order of $30,000.

At this stage of taxonomy development, no formal decision rule is proposed for determining routinely what level of decision analysis should be used. In this case, however, it is clear that any plausible decision rule would indicate a large amount of decision analysis, since only one of the seven key situation characteristics is absent (difficult choice), and only two of the other ten favorable situation characteristics are absent (indeterminable uncertainty and large budget).[1] However, since only a small budget ($30,000) for analysis was available, its size alone easily determined the dimensions of the project without any need for a formal decision rule.

4.1.2 <u>Type of decision analysis to use on export control decision</u> - The following discussion indicates the appropriate type of analysis for the export control problem. This discussion, which treats each analytic option, should be considered in conjunction with Table 3-2 above.

The analysis was used in a display rather than in an optimization mode (A1342) because the scope of the analysis, at the client's request, was not comprehensive (A222); certain political dimensions of value such as impact on detente were deliberately excluded from the analysis. The display of the decision's impact on those dimensions of value that were explicitly modeled (economic, military, and so forth), however, permitted an evaluation of how large the excluded political considerations would need to be in order to change the preferred option.

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[1]Watson and Brown (1975/1) presents an attempt to put a value on this particular analysis, after-the-fact.

A computer was used (A1521) because the decision was expected to recur about every two years (S1124), the stakes were high (S1444), and many input iterations (A61533) were expected. The large number of input iterations was indicated because this was a very controversial decision (S2352).

The complexity of the analysis was low (A211) because of a need to communicate (P321) the arguments in order to justify the decision (S2343) and because few of the conditions indicating complexity were met (see Table 3-2). In particular, only one probability distribution was modeled (on one dimension of value--military threat).

Subsequent acts were not explicitly modeled (A3130) because they did not have enough impact (S1641) to justify any explicit modeling.

On the other hand, value was decomposed extensively (A3222) into its four major dimensions (U.S. computer sales, allied goodwill, military threat, and other) and one dimension, military threat, was decomposed into sixteen specific variants. One reason was that the sources of preference judgment were different (S2213) and partly because the decision was controversial (S2352), especially regarding trade-offs among value dimensions (for example, how much improvement in computer sales will compensate for a deteriorating military threat.)

The decompositions were all linear (A32511) because of a need for both pre- and post-justifications (S2343).

The value scales used a "floating base" (A4322) because the technical problems of valuation of each dimension were not very difficult (S1510) and because experienced staff (S2522) were available to handle the greater technical subtlety involved.

In performing the calculations, simulation was not needed (A5310) because the model structure was not complex (A211).

4.1.3 <u>Sequential taxonomy matching</u> - Direct use of the universal taxonomy, as illustrated above, may present substantial problems of elicitation if all potentially relevant characteristics are involved. Since there are hundreds of situation characteristics to measure, it may be difficult to measure any one of them, let alone all of them. That is, it may be very difficult to locate precisely any given situation in situation space.

However, for any particular choice (for example, whether to use decision analysis at all), only some of the situation dimensions are relevant and even all of those may not need to be evaluated to make a given analytic choice. the choice of whether to use decision analysis or not may be resolved on the grounds of stakes alone if they are small enough. For example, the small size of the budget (S2562) and the large size of the stakes (S1444) in the COCOM Case (see Section 4.1.1) immediately determined the amount of analysis.

Thus, a sequential elicitation of situation characteristics is often indicated. In principle, a flow chart could be constructed to control the sequence of situation characteristic elicitation. The answers to each situation question either indicate an analytic choice or call up a new question. Figure 4-1 shows notionally the form such a flow chart might take, but it does not represent a considered proposal. A complete flow chart of this form would represent, in effect, a manual of applied decision analysis.

4.2 Indirect Taxonomy Matching Through a Specific Taxonomy

Since relevant situational characterizations tend to be difficult to accomplish, it is desirable to seek mediating characterizations that enable an easy characterization to serve as a surrogate for a relevant one. For this reason, specific taxonomies, which are specific to a particular field of decision-making and which are based upon concepts that are familiar in the field, need to be developed in addition to the universal taxonomy presented above, which is not specific to a particular area of decision making.

Figure 4-2 illustrates the manner in which a situation can be characterized along both specific and universal taxonomies in order to determine the appropriate decision-analytic techniques. The decision to neutralize an enemy-held island, which may cause a global war, might be characterized as a "crisis" situation on the specific taxonomy. This characterization is associated with the universal dimensions of "multiple value source," "controversial," and "high stakes." Through matching generalizations, the situation characterization indicates that a substantial scale of decision analysis, requiring explicit disaggregation of value, is indicated. In conjunction with other specific or universal descriptions of the situation, this matching indicates specific analytic choices, step-through simulation model structure, and decomposed valuation.

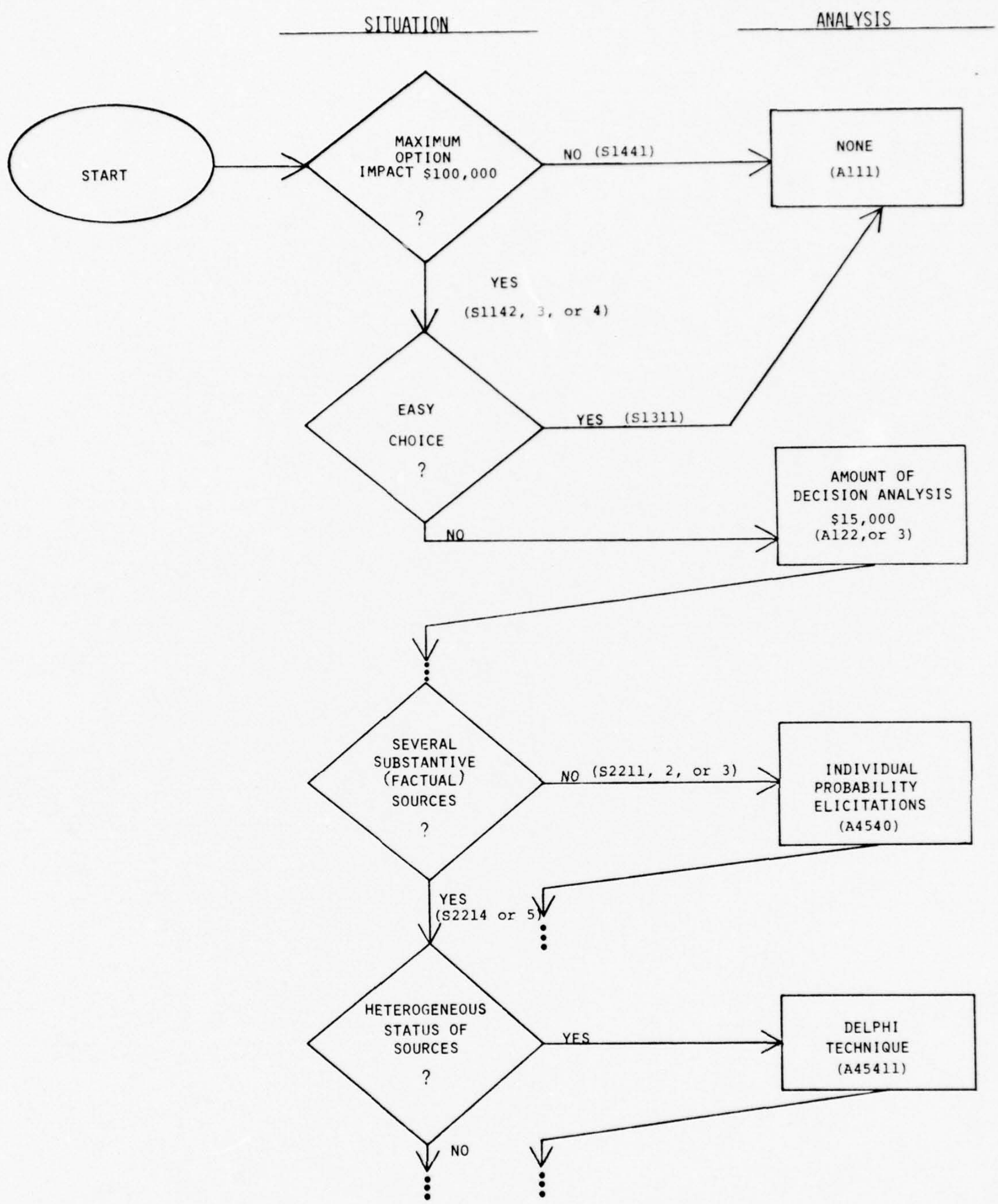

Figure 4-1
ELICITATION SEQUENCE FLOW CHART

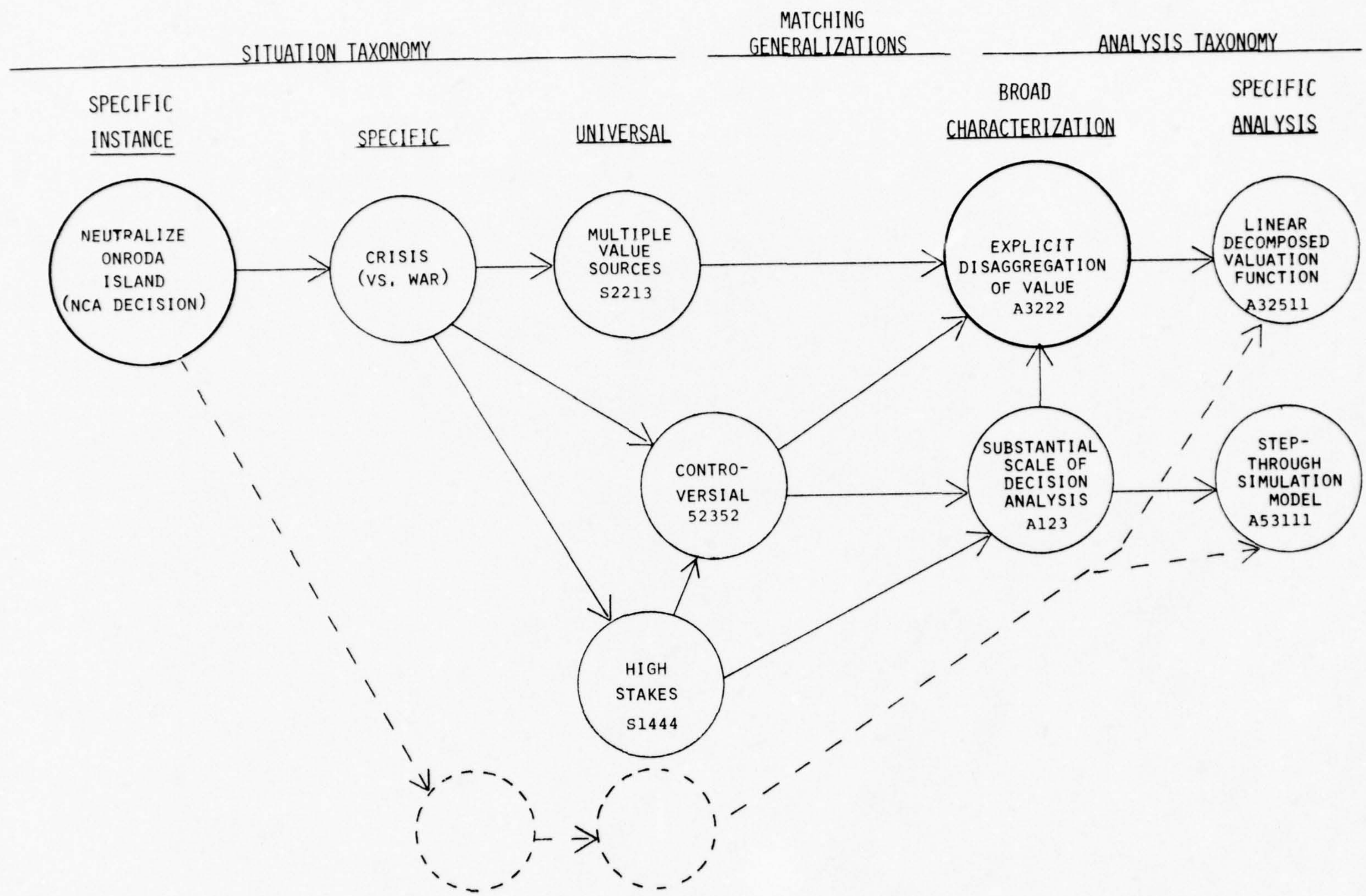

Figure 4-2
ILLUSTRATIVE USE OF TAXONOMY MATCHING

Table 4-2 illustrates another example of how a specific taxonomy matching might be developed. The specific characteristic of business-versus-government decisions is analyzed to determine how much decision analysis to use. Table 4-2 indicates that government decisions are more frequently associated with the universal situation characteristics favoring decision analysis than are business decisions. Table 4-2 suggests, therefore, that, as a general rule (modified of course by particular circumstances, that is, other specific or universal situation characteristics), government decisions favor decision analysis more than business decisions do.

The specific taxonomy examples presented above are intended only to present the idea and point the direction for future research.[2]

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[2] In addition, a start has been made in Sections 1, 2, and 6 of Brown et al. (1974) on developing a specific taxonomy for naval tactical situations.

Universal Taxonomy

Characteristics Favoring DA

	Specific Characteristics	
	Government	Business
High expected number of occurrences (S1124)		X
Difficult choice (S1312)	X	
High stakes (S14)	X	
Difficult net valuation (S1512)	X	
Several sources for both substantive and preference inputs (S2215)	X	
Controversial (S2352)	X	
Need for post-decision justification (S2343)	X	

Specific matching conclusion: government decisions tend to favor the use of decision analysis more than business decisions.

Table 4-2: APPLICATION OF SPECIFIC TAXONOMY

5.0 CONCLUSIONS

5.1 Implications of Work Completed

It is important not to confuse the grand design of the total taxonomy matching task with the modest and tentative beginning which this report represents. What is proposed here is no more than a conceptual framework with some notional substance. Even at its completion, the taxonomy matching will represent essentially a vehicle for communicating the state-of-the-art of applying decision analysis and will make only incidental contributions to the state-of-the-art itself. Possibly the structure developed will encourage methodological inquiry simply by providing a convenient vehicle for dissemination of the results of such inquiry. The main value of the taxonomy, however, must lie in being a prompter, a pointer, and, to some extent, a stage setter for further, more substantive research.

However, this report does carry some of the tentative methodological doctrine that a few specific decision analysts at Decisions and Designs, Incorporated have developed. That doctrine, cast in this format, may stimulate some controversy or methodological inquiry especially when it conflicts with the textbook paradigms of decision analysis (for example, the modeling of subsequent acts as events). However, the proper vehicle for research aimed at doctrinal persuasion, at least in the first instance, is in topic oriented technical reports, not here.

5.2 Future Research

Since this project is only a tentative first step toward the codification of decision analysis, we are well aware that much remains to be done to arrive at something even approximating a definitive framework for ourselves and others in the field to work with. Toward this end, we are soliciting comments and suggestions from colleagues and interested researchers. If responses are sufficiently encouraging, it is planned to modify this material and ready it for general publication.

The following are some proposals for change or development under current consideration:

1. Re-order items in the performance measure taxonomy by putting the "overall" categories first;

2. Include "Don't Know" and "Not Modeled" categories in the taxonomies;

3. Replace the last (response) digit in the taxonomies with a letter. Thus, "binary options" might be referenced as "S123A" instead of "S1231";

4. Expand Section A45, elicitation techniques;

5. Resolve a possible conflict concerning P112 and P123: Is the performance measure, "effective disaggregation," meaningful, or is it the same as "posing meaningful questions?";

6. Review terminology to be used; for example, should "substantive" or "uncertainty," describe a type of input in S221?; and

7. Expand the bibliography.

From this tentative beginning, a number of promising avenues for research appear, including the following:

1 Refine and enrich the taxonomic and matching material in this report in the light of more thorough investigation of the same issues, and of a wider range of decision-analytic experience (involving organizations other than DDI);

2. Develop specific taxonomies and matching generalizations for particular purposes, for example, a matching taxonomy to select decision aids by task force commanders for tactical naval battle decision situations. This development could be a valuable adjunct to an ongoing program sponsored by the Office of Naval Research on Operational Decision Aids. This particular problem is discussed in Appendix A of Payne et al. (1974) and Sections 1, 2, and 6 of Brown et al. (1974);

3. Develop an analogous analysis to that presented here directed to the problem of matching decision situations with information needs (as opposed to analytic approaches). Such an inquiry, or a specific version that is specific to Naval tactics, might be a valuable adjunct to the development of the information component of a tactical flag command center (TFCC) of the type currently under consideration in the U.S. Navy;

4. Extend generalizations proposed here to the point of proposing specific decision rules which go beyond the simple listing of favoring characteristics;

5. Codify the state-of-the-art decision analysis with respect to specific technical issues, one at a time. This codification would call for a richer and more definitive expansion of sub-sections of Section 3.2, for example, expanding an individual row of Table 3-2;

6. Develop an implementation procedure for the taxonomy matching, for example, by proposing and trying out in practice specific procedures to help a decision maker or a technician evaluate candidate decisions for decision analysis (e.g., by developing a filtering procedure along the lines of Figure 4-1); and,

7 Develop interactive computer graphic programs to streamline the filtering procedure referenced in 6 above.

APPENDIX A

SITUATION TAXONOMY

1 Decision Substance

11 BASIC SITUATION

111 current/contingent choice
112 expected # of occurrences
(113 operating/information act)
119 other basic situation

12 OPTIONS

(121 broad/narrow)
122 clear/fuzzy
123 complexity of decision options
124 radical/adaptive
125 static/dynamic
129 other options

13 DECIDABILITY

131 difficulty of choice
132 unfamiliarity
133 key considerations
134 other decidability

14 STAKES

141 resources committed
142 cost swing
143 value swing
144 maximum option impact
145 expected irrationality cost
149 other stakes

15 OUTCOME VALUATION

151 difficulty of net valuation
(152 # of value dimensions)
(153 measurable value?)
(154 natural combinability of values)
(155 timing)
(156 difficulty of component valuation)
159 other outcome uncertainty

16 OUTCOME UNCERTAINTY

161 # of uncertainties
162 determinability
163 high/low uncertainty
164 subsequent acts
(165 type of evidence)
166 hindsight monitoring
169 other outcome uncertainty

19 OTHER DECISION SUBSTANCE

2 Decision Process

21 REACTION TIME

211 minutes
212 hours
213 days
214 months

22 ANALYTIC PROCESSES

221 # of input sources
222 analytic team
223 constraints on analytic method
224 documentation
229 other

23 ORGANIZATIONAL PROCESSES

(231 initiation)
232 responsibility
(233 coordination)
234 justification
235 controversiality
236 performance control
237 rational-actor model
238 risk attitude
239 other organizational processes

24 DECISION-MAKER CHARACTERISTIC

241 role in organization
242 personal characteristics
249 other

25 RESOURCES AVAILABLE

251 computational facilities
252 staff
253 decision analysis expert
254 availability of decision-maker
(255 availability of assessors)
256 dollars available
259 other resources

29 OTHER DECISION PROCESSES

291 negotiation

Table A-1: SITUATION TAXONOMY – SUMMARY

1 Decision Substance

The following dimensions describe the substance of a decision as opposed to the setting in which the decision is to be made.

11 Basic Situation

111 Current/contingent choice - Does the situation demand a choice which will result in a current or contingent action?

1111 Current - e.g., mobilize NATO forces immediately.

1112 Contingent - e.g., mobilize NATO forces if and when the probability of Warsaw Pact forces mobilizing exceeds .55.

112 Expected number of occurrences - a probability weighted average of the number of times that the decision must be made (including the first time).

1121 Expected number of occurrences < 1

1122 Expected number of occurrences = 1 (e.g., a current choice or a contingent choice that will occur twice if it occurs at all and has a 50% chance of occurring).

1123 Expected number of occurrences = 2

1124 Expected number of occurrences > 2

113 Operating/information act - Will the decision result in taking an operating act or an act to seek information?

1131 Operating - e.g., shoot at an unidentified plane.

1132 Information - e.g., seek information on an unidentified plane's identity.

119 Other basic situations.

12 Options

121 Broad/Narrow - Is a commitment required at a broad or narrow level? (A narrow level is typically a subset of a broad one.)

1211 Broad - e.g., go North or go south.

1212 Narrow - e.g., go to Fairbanks, Alaska, or go to Miami, Florida.

122 Clear/Fuzzy - Are the options clearly specified or not?

1221 Clear - e.g., selecting one of five bidding contractors.

1222 Fuzzy - e.g., selecting criteria to use in selecting a contractor.

123 Complexity of decision options - How many decision options are under consideration?

1231 Two (a binary choice).

1232 Three to twelve.

1233 More than twelve (discrete).

1234 One scalar - e.g., what price to change.

1235 Small vector - e.g., what values to assign to three design parameters.

1236 Large vector.

1239 Other

124 Radical/adaptive - Is the decision within the realm of the decision maker's current practice?

1241 Radical - outside of the realm of current practice and the alternatives are very different, (e.g., a decision to drop a product).

1242 Adaptive - involving minor changes in current practice and the alternatives are very similar (e.g., a decision to raise the price of a product).

125 Static/dynamic - Is this decision final or can it be modified over time?

1251 Static - The decision is to be made now once and for all (e.g., a declaration of war).

1252 Dynamic - The commitment can be modified, possibly continuously (e.g., taking an increasingly bellicose stance toward a potential enemy, maneuvering a ship).

129 Other options

13 Ease of Decision

131 Difficulty of choice - Is there a lot of room for improvement over informal decision making?

1311 Routine or obvious - Informal techniques leave little room for improvement.

1312 Difficult - There is much room for improvement over informal decision-making techniques. Decision maker is perplexed about what to do and there is a high "cost of confusion."

132 Unfamiliarity - How foreign is the choice to the decision maker's experience?

1321 Low - familiar to the decision maker's experience.

1322 High - foreign to the decision maker's experience.

133 Key consideration - in this case, what is the key determinant of a good decision?

1331 Option generation - generating a set of viable options.

1332 Information - gathering information to support a choice.

1333 Inference - drawing inferences from available information.

1334 Choice - choosing from among a set of options.

1339 Other considerations.

139 Other decidability

14 Stakes

141 Resources committed - What total amount of resources are involved with the decision (e.g., value of facilities engaged)?

1411 Low - less than $200,000.

1412 Medium - $200,000 to $2 million.

1413 High - greater than $2 million.

142 Cost swing - What is the difference in cost between the least expensive and most expensive option?

1421 Low - less than $100,000.

1422 Medium - $100,000 to $1 million.

1423 High - greater than $1 million.

143 Value swing - What is the difference in value between the best and worst plausible outcomes (regardless of option)?

1431 - Less than $1 million.

1432 - $1 million to $40 million.

1433 - $40 million to $100 million.

1434 - Greater than $100 million.

144 Maximum option impact - What is the dollar equivalent difference in outcome attributable to the choice of best decision over worst reasonable decision?

1441 - less than $100,000.

1442 - $100,000 to $5 million.

1443 - $5 million to $10 million.

1444 - Greater than $10 million.

145 Expected option impact - What is the expected value of the differences attributable to option choice?

1451 - less than $50,000.

1452 - $50,000 to $2 million.

1453 - $2 million to $5 million.

1454 - greater than $5 million.

146 Expected irrationality cost - What is the room for improvement in the user's decision making process (the expected cost of choosing an option other than that indicated by an "impeccable" decision analysis)?

1461 Low - less than $150,000.

1462 Medium - $150,000 to $500,000.

1463 High - greater than $500,000.

149 Other stakes

15 Outcome Valuation

151 Difficulty of net valuation - How difficult is it to compare the attractiveness of possible outcomes? (Specific elements of this characterization are covered below in items S152 - S155.)

1510 Not very - e.g., for a single criterion with a natural metric.

1511 Moderately.

1512 Very - e.g., for multiple conflicting intangible criteria.

152 Number of value dimensions - Is a single value criterion (measure of effectiveness) sufficient or are multiple criteria important?

1521 Single

1522 Few

1523 Many

153 Measurable value - To what extent does a natural metric exist for the value dimensions?

1530 No natural metric - e.g., for quality of life.

1531 Approximate metric - e.g., GNP as a metric for standard of living.

1532 Exact metric - e.g., dollars as a metric of income.

154 Natural combinability of value - How natural is it to combine the dimensions of value into a single index?

1541 Low - e.g., in the case of many conflicting intangible variables.

1542 Moderate.

1543 High - e.g., for different additive components of a single variable such as cost.

1549 Other - e.g., high for some but not for all.

155 Timing - early/late - Are the value dimensions characterized by early or late evaluation dates?

1551 Early - e.g., cost of a contract.

1552 Late - e.g., long-run impact on U. S. military standing.

156 Difficulty of component valuation - How difficult is it to value outcomes on each criterion scale?

1561 Low

1562 Medium

1563 High

159 Other outcome valuations.

16 Outcome Uncertainty

161 Number of uncertainties - How many uncertain quantities influence the decision?

1611 One

1612 Few

1613 Many

162 Determinability - How difficult is it to determine the appropriate probability distribution(s) of the uncertain quantities?

1621 Low

1622 Medium

1623 High

163 High/low uncertainty - What is the "amount" of uncertainty in the uncertain quantities (e.g., as represented in the "spread" of the probability distribution)?

1630 None

1631 Low

1632 Medium

1633 High

164 Subsequent acts - To what degree do subsequent acts impact the decision outcome?

1641 Low

1642 Medium

1643 High

165 Type of evidence - What is the nature of evidence available for resolution of uncertainty?

1651 Historical record.

1652 Direct judgment only.

1653 Indirect judgment - e.g., based on conditioning events.

166 Hindsight monitoring - How accurately and promptly can the outcomes be determined by hindsight?

1661 Low - e.g., having to wait years to know whether there were mines at the entrance of the Dardanelles in 1914.

1662 Medium.

1663 High - e.g., discovering within hours that a bombing mission was successful.

169 Other outcome uncertainties

19 Other Decision Substance

2 Decision Process

In terms of the user's analytic options (as opposed to the technician's options), the organizational and personal setting within which a decision is to be made may be of even greater importance than the specific substance of the decision. Thus, we may be interested in the personal characteristics of the decider, the organizational setting within which he operates, or external constraints on the decision process.

21 Reaction Time - How much reaction time is available between the time that the decision is recognized and the time that a commitment is required?

211 Minutes - e.g., in deciding to shoot an approaching unidentified plane.

212 Hours - e.g., in the Pueblo incident.

213 Days - e.g., in a NATO mobilization decision.

214 Months - e.g., in planning a reconnaissance system.

22 Analytic Process

221 Number of input sources - How many sources will provide input data?

2211 Single for all inputs - All inputs will come from a single source.

2212 Single for each input - There will be several input sources, but only one source for each input.

2213 Several preference sources - There will be several (e.g., preference value) input sources but only a single source for substantive input.

2214 Several substantive sources - There will be several sources for substantive (e.g.,uncertainty) input but only a single source for value input.

2215 Several for both - There will be several substantive and preference sources.

222 Analytic Team

2221 Number of team members - How many people will actually perform the analysis?

22211 Single - e.g., the decision maker himself, a member of his staff, or an outside consultant.

22212 Multiple - e.g., a group of staff members or a horizontal task force comprised of several people of equal rank in the organization.

2222 Type of analyst - Who will actually perform the analysis?

22221 The decision maker himself.

22222 A member of the decision maker's staff.

22223 An outside consultant.

2229 Other distinctions.

223 Constraints on analytical method - What established procedures constrain the analytic method?

2230 None - The analysis is unconstrained.

2231 Required - The analysis is required to conform to established procedures.

2239 Other

224 Documentation - What procedures constrain reporting and documentation?

2240 None

2241 Required - A certain form of documentation is required.

2249 Other

23 Organizational Process - These dimensions deal with the way in which a particular decision is articulated within the organization and the way the decision is initiated, used, and controlled.

231 Initiation

2311 How is the analysis initiated?

23111 Spontaneously in response to unanticipated developments.

23112 Scheduled ahead of time.

23119 Other

2312 Who initiates the decision?

23121 The decision maker

23122 His staff

23123 His superior

23124 A subordinate

23125 A peer

23129 Other

232 Responsibility - Where, in the organization, is the responsibility for the decision?

2321 Role of decision analysis user - What role does the decision analysis user serve in the decision process?

23211 Firm decision - He will make the final decision.

23212 Tentative decision - He will make a decision that is subject to someone else's revision.

23213 Recommendation - He will make a recommendation.

23214 Information - He will provide information for someone else's decision.

23219 Other

2322 Dispersion of decision responsibility - How is the responsibility for the decision dispersed?

23220 Not

23221 Horizontally

23222 Vertically

23229 Other

233 Coordination - To what degree must the decision coordinate with other higher, lower, or collateral decisions?

2330 Not at all

2331 Moderately

2332 Very much

234 Justification - Is the analysis required as justification before or after a decision is made?

2340 No

2341 Pre only

2342 Post only

2343 Both pre and post

235 Controversial - How controversial is the decision?

2350 Not

2351 Moderately

2352 Very

236 Performance control - what type of accountability, evaluation, or reward system is in operation?

2360 None - The decision maker is his own master.

2361 Loose

2362 Tight - The decision maker operates under very strict control.

2369 Other - e.g., the decision maker is controlled by more than one superior (as with the Chief of Naval Operations).

237 Rational-actor model - How well is the organizational decision process approximated by a rational actor model?

2371 Poor approximation.

2372 Good approximation.

238 Risk Attitude - Does the process require the consideration of attitude toward risk?

2380 Risk neutral.

2381 Risk averse.

2382 Risk seeking.

2389 Other non-linear utility function

239 Other organizational processes

24 Decision Maker Characteristics

What are the characteristics of the person making the decision?

241 Position in organization

2411 Authority level - What authority does the decision maker command?

24111 Low - first-line manager (e.g., Lieutenant).

24112 Medium

24113 High - top management (e.g., General Officer).

2419 Other - e.g., What type of organization does the decision maker belong to?

242 Personal characteristics

2421 Familiarity with decision analysis - How familiar is the decision maker with decision-analytic techniques?

24211 None

24212 Little

24213 Much

2429 Other, e.g., management style.

249 Other characteristics

25 Resources Available

251 Computational facilities - How much computational facility is available for analysis?

2510 None

2511 Some - small computer.

2512 Much - powerful computer.

252 Staff - What type of staff support is available to the decision maker?

2520 None

2521 Modest - a few or untrained people.

2522 Strong - many competent people.

253 Decision-analytic expert - Does the decision maker have access to decision-analytic expertise either in-house or through consultants?

2530 None

2531 Low

2532 High

254 Decision-maker availability - How available will the decision maker be throughout the course of the analysis?

2540 Not

2541 Little

2542 Much

255 Availability of assessors - How available will the assessors be throughout the course of an analysis?

2550 Not

2551 Low

2552 High

256 Dollars available - How much money is available for the analysis?

2561 Less than $15,000.

2562 $15,000 to $50,000.

2563 Greater than $50,000.

259 Other resources

29 Other Decision Processes

291 Negotiation - Are there two or more actors with conflicting interests?

2910 No - single actor

2911 Two

2912 More

APPENDIX B

ANALYTIC OPTION TAXONOMY

1 USER'S OPTIONS

11 USE DECISION ANALYSIS AT ALL?

111 intuitive
112 decision analysis
119 other

12 DOLLAR AMOUNT OF ANALYSIS

121 low
122 medium
123 high

13 ROLE OF DECISION ANALYSIS

131 private/public aid
132 prescribed/optional
133 contingent/current analysis
134 optimization/display
135 communication

14 ORGANIZATION

141 analysis source
142 input source
143 "vest-pocket" relation to decision-maker?

15 RESOURCES

151 use a decision analysis expert?
152 use a computer?

2 MODEL APPROACH OPTIONS

21 COMPLEXITY OF ANALYSIS

211 simple
212 moderately complex
213 very complex

22 COMPREHENSIVE/PARTIAL ANALYSIS

221 comprehensive
222 partial

23 APPROXIMATE ANALYSIS?

230 no
231 yes

3 INPUT STRUCTURE

31 UNCERTAINTY

311 explicit modeling
312 time horizon
313 subsequent acts
314 event sequency ordering
315 detail level
316 degree of grouping

32 VALUE

321 comprehensive?
322 decomposed?
323 partial list?
324 single index?
325 function?

33 SPECIAL FORMS

331 Markov
332 Pareto
333 linear programming

4 INPUT SPECIFICATION

41 DECISION OPTIONS

411 specificity of definition
419 other

42 EVENTS

421 scenarios
422 specific
429 other

43 VALUE CRITERIA

431 units
432 base
433 evaluation date(s) for time stream

44 INDIRECT ASSESSMENTS

441 conditioned assessment model?
442 Bayesian updating?
443 decomposed assessment model?
444 regression?
449 other

45 ELICITATION TECHNIQUE

451 for discrete probabilities
452 for continuous variables
453 for values
454 use group elicitation?

5 OUTPUT

51 SPECIFICATION

511 preferred decision
512 single value for each option
513 value distributions
519 other

52 DISPLAY FORMAT

521 graphic
522 computer
529 other

53 ANALYTIC DEVICES

531 use simulation
539 other analytic devices

6 MODEL MANAGEMENT

61 MODEL DYNAMICS

611 combining
612 pooling
613 sequential modeling
614 decision option scanning
615 input iteration

62 CONTINGENT ANALYSIS INPUT SEQUENCE

621 values
622 priors
623 likelihood
624 data

Table B-1: ANALYTIC TAXONOMY – SUMMARY

1 User's Options - those options that should be considered by the decision maker rather than the analyst.

11 Use decision analysis at all? - Should any of the following decision analytic techniques be used or should intuitive decision-making techniques be used?

111 Intuitive - Use intuitive decision-making devices.

112 Decision analysis - Use decision analysis.

119 Other - Use another decision-making technique.

12 Dollar amount of analysis - What amount of money should be devoted to the analysis effort?

121 Low - less than $15,000.

122 Medium - $15,000 to $50,000.

123 High - greater than $50,000.

13 Role of decision analysis - What role should the analysis serve in the decision-making process?

131 Private/public aid - Should the decision analysis serve as a personal aid for the decision maker, or should the analysis serve a more public function?

1311 Private

1312 Public

132 Prescribed/optional - Should the decision indicated by the analysis be prescribed, as in an automatic control system, or should the indicated decision be optional?

1321 Prescribed

1322 Optional

133 Contingent/current analysis - Should decisions that are anticipated in the future be analyzed in advance, or should they be analyzed only when the decision situation has materialized?

1331 Contingent - analyzed in advance.

1332 Current - analyzed when the decision is current.

134 Optimization/display only - Should a closed optimization model be used [See chapter 18 of Brown, et.al. (1974)], regardless of what display options are used? (Display options are presented in A51 below.)

1341 Optimization

1342 Display only

135 Communication - Should the analyses serve to communicate the reasons for a choice?

1350 No

1351 Yes

14 Organization - How should this analysis effort be organized?

141 Analysis source - Who should take responsibility for performing the analytic work?

1411 Decision maker

1412 Staff member

1419 Someone else

142 Input source - Who should be responsible for providing the model inputs?

1421 Decision maker

1422 Analyst

1423 Expert

143 "Vest pocket" relation to decision maker - Should the analyst work in a close, "vest pocket" relation to the decision maker?

1430 No

1431 Yes

15 Resources - What special resources should be devoted to the analysis?

151 Use a decision-analytic expert? - Should a decision analysis expert be used to provide assistance in the analytic effort?

1510 No

1511 Yes

152 Use a computer? - Should a computer be used in the analysis?

1520 No

1521 Yes

2 Model Approach Options - These options concern the types of decision-analytic modeling techniques to use.

21 Complexity of analysis - On the whole, how complex should the analysis effort be?

211 Simple

212 Moderately complex - e.g., on a par with a 100-node decision tree.

213 Very complex

22 Comprehensive/Partial analysis - Should the analysis encompass only a part of the complete problem or purport to reflect all relevant considerations?

221 Comprehensive - reflect all relevant considerations.

222 Partial - encompass only a part of the complete problem.

2221 Inference only - perform an analysis to draw inferences from the data.

2222 Single value dimension - consider only one of the several relevant dimensions of value.

2229 Other - perform some other part of the complete analysis.

23 Approximate analysis - Should the analysis be performed using only approximations of the variables (e.g., values, probabilities, decision options)?

230 No

231 Yes

3 Input Structure - those alternative ways of structuring the inputs to the analysis.

31 Uncertainty - How should uncertain events be structured for the analysis?

311 Explicit modeling - Is uncertainty explicitly encoded?

3110 No certain equivalents only.

3111 Simple measures of uncertainty - e.g., credible intervals.

3112 Complete probability distributions.

312 Time horizon - Over what period of time should events be explicitly modeled?

3121 - Short

3122 - Long

313 Subsequent acts - How should acts subsequent to the initial choice (e.g., an act based upon the outcome of a test marketing effort) be treated in the analysis?

3130 Not explicitly modelled.

3131 Modelled in preposterior format.

3132 Modelled as events.

3139 Other

314 Event sequence ordering - In what order should the events be structured in the analysis?

3141 Chronological

3149 Non-chronological

315 Detail level - What degree of detail should be included in structuring the inputs?

3151 Low - e.g., binary grouping of variables.

3152 Medium - e.g., grouping by 10 bracket medians.

3153 High

316 Degree of grouping - To what degree should uncertain quantities be grouped?

3161 Low

3162 High

32 Value - How should valuation be structured in the analysis?

321 Comprehensive - Should an attempt be made to use a comprehensive valuation measure, which considers all items of concern to the decision maker?

3210 No

3211 Yes

322 Decomposed - To what degree should the overall value dimension be decomposed into its constituent parts (e.g., decomposing profit into units, price, and profit margin)?

3220 None

3221 Modest

3222 Substantial

323 Partial list - Should only a partial list of value criteria be used in the analysis?

3230 No

3231 Yes

324 Single index - Should all value dimensions be aggregated into a single index? If so, how should it be done?

3240 No

3241 Yes

32411 Adjustment - Treat subsidiary value criteria by making trade-off adjustments to the main criterion.

32412 Utility - Combine all value criteria into a single utility measure.

32419 Other - Use another method to arrive at a single valuation index.

325 Function - If 32412, should multi-attributed value be expressed in the form of a mathematical function? If so, what function?

3250 No

3251 Yes

32511 Linear

32519 Other function

33 Special forms - Should any special analytical paradigms or techniques be used?

331 Markov - Should a sequence of events be treated as a Markov Process?

3310 No

3311 Yes

332 Pareto - Should the concept of Pareto optimality be used in considering decision options?

3320 No

3321 Yes

333 Linear programming - Should linear programming techniques be used to optimize the choice?

3330 No

3331 Yes

339 Other special forms - Should other special forms of analysis be used?

3390 No

3391 Yes

4 Input Specification - This category considers how inputs should be specified once they have been structured.

41 Decision options - How should the decision option space be explored?

411 Specificity of definition - How do the analyzed decision options compare in specificity to the real decision options?

4111 Real option - Evaluate the action, e.g., whether to set out for Alaska (with the exact location determined later).

4112 Narrower variant of real option - e.g., go to Fairbanks, Alaska.

4113 Broader class - e.g., go North.

419 Other

42 Events - How should uncertain events be specified in the analysis?

421 Scenarios - Incorporate events by specifying scenarios.

422 Specific - Use specific events.

429 Other - Use another method of specifying events.

43 Value criteria - How should the valuation be specified?

431 Units - What should the units of value be?

4311 Natural - such as dollars, hours, etc.

4319 Other - such as utiles.

432 Base - What kind of reference base should be used for valuation?*

4321 Fixed zero - Use an absolute scale.

4322 Floating zero - Use a relative or incremental scale (i.e., a scale that relates all values to those of a single, possibly hypothetical, alternative).

433 Evaluation date(s) for time stream - What evaluation date or dates should be specified in the analysis?

4331 Present value - Reduce all values to the present date.

4332 Future value - Project all values to a specified future date.

4333 Time flow - Present the values as a flow over some specified time period.

4339 Other

44 Indirect assessments - What indirect assessment techniques should be used to specify inputs?

441 Conditioned assessment - the number of conditioning tiers (treating uncertainty explicitly by considering, for each decision option, a probability distribution on the events that impact the valuation).

4410 None

4411 Few

4412 Several

4413 Many

442 Bayesian updating - Should Bayes' Theorem be utilized to process information bearing on some model inputs?

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*This concept is clarified in Brown, et al. (1974) pp 363-4, 96.

4420 No

4421 Yes

443 Decomposed assessment model - Should any input be specified by using a decomposed assessment model that breaks the inputs into their constituent parts?

4430 No

4431 Yes

444 Regression - Should any of the inputs be determined by using regression analysis?

4440 No

4441 Yes

449 Other - Should other indirect assessment techniques be used?

4490 No

4491 Yes

45 Elicitation technique - What elicitation techniques should be used?

451 For discrete probabilities

4511 Odds - Elicit relative likelihoods.

4512 Probabilities - Elicit probabilities.

4519 Other

452 For continuous variables

4521 Fixed probability - e.g., fractiles or credible intervals.

4522 Fixed interval

4529 Other

453 For values

4531 Reference gamble

4532 Direct rating

4539 Other

454 Use group elicitation - Should group elicitation be used for probabilities or values?

4540 No

4541 Yes

45411 Delphi

45412 Delbecq

45419 Other

5 Output

51 Specification - What results should be presented?

511 Preferred decision - Should the preferred decision be presented?

5110 No

5111 Yes

512 Single value for each option - Should a single value (e.g., an expected value) be presented for each option?

5120 No

5121 Yes

513 Value distributions - Should a distribution of value be presented for each option?

5130 No

5131 Yes

519 Other

52 Display Format - How should the specified output be displayed?

521 Graphic - Should a graphic display of the analytic results be prepared?

5210 No

5211 Yes

522 Computer - Should a computer supply the display?

5220 No

5221 Yes

529 Other

53 Analytic Devices

531 Use simulation - Should the analysis of uncertainty be addressed using Monte Carlo simulation?

5310 No

5311 Yes

53111 Use step-through? - Should the analytical device of step-through simulation be used (See Brown et al., 1974)?

531110 No - Use regular simulation.

531111 Yes

53112 Number of trials - How many simulation trials should be used?

531121 Few

531122 Many

539 Other analytic devices - What other analytic devices should be used?

5391 Grouping - Should grouping devices such as bracket medians be used?

53910 No

53911 Yes

5392 Pruning - Should pruning devices such as dominance be used?

53920 No

53921 Yes

6 Model Management

61 Model Dynamics

611 Combining - Should several models be linked together in series?

6110 No

6111 Yes

612 Pooling - Should several simultaneous models be linked together in parallel?

6120 No

6121 Yes

613 Sequential modeling - Should the problem be modeled sequentially?

6130 No

6131 Yes

614 Decision option scanning - How should the decision option space be scanned?

6141 Complete enumeration - by examining all possible decision options.

6142 Sequential

6149 Other

615 Input iteration - How much should inputs be modified within the same model structure (e.g., sensitivity analysis)?

6151 Values

61511 Low

61512 Medium

61513 High

6152 Probabilities

61521 Low

61522 Medium

61523 High

6153 Both values and probabilities

61531 Low

61532 Medium

61533 High

62 Contingent analysis input sequence - When should the various inputs be entered into a contingent analysis (A1331 above)?

621 Values - When should values be entered?

6211 Early - contingently, before the decision is made.

6212 Late - when the decision is made.

622 Prior probabilities

6221 Early

6222 Late

623 Likelihoods - Likelihoods for indicators

6231 Early

6232 Late

624 Data

6241 Early

6242 Late

APPENDIX C

PERFORMANCE MEASURE TAXONOMY

1 Quality of Decision

11 LOGIC OF CHOICE

111 conceptual completeness
112 effective disaggregation
113 sound predictions
114 good overall logic
115 scope
119 other

12 QUALITY OF INPUT

121 good data gathering
122 good management of staff/ expertise
123 posing meaningful questions
124 good overall input quality
129 other

2 Time and Cost

21 ELAPSED TIME

211 short elapsed modeling
212 fast input assignment
213 fast calculation
214 fast interpretation
215 short overall net elapsed time
219 other

22 COSTS

221 inexpensive analysis
222 inexpensive input assignment
223 inexpensive calculation
224 inexpensive overall
229 other

3 Other Considerations

31 ACTIVITY PRECEDING CHOICE PROCESSES

311 good environment monitoring
312 good decision identification
313 good option generation
314 good pre-analysis of anticipated decisions
319 other

32 ACTIVITY FOLLOWING CHOICE PROCESSES

321 good decision communication
322 good hindsight evaluation
323 effective implementation
329 other

33 ORGANIZATIONAL AND OTHER NON-"CHOICE SPECIFIC" IMPACTS

331 improved information
332 improved command, control, and communication
333 improved body of applied precepts
339 other

Table C-1: PERFORMANCE MEASURES – SUMMARY

1 Quality of decision - the quality of the reasoning or logic and the quality of the inputs.

11 Logic of choice - making choices that are in logical agreement with available information.

111 Conceptual completeness - taking all important considerations into account, and avoiding serious errors of approximation.

112 Effective disaggregation - dividing the problem into manageable subproblems.

113 Sound predictions - making sound inferences from the available data.

114 Good overall logic - a summary measure of making choices that are in logical agreement with available information. This includes performing a technically competent analysis.

115 Scope - addressing the complete problem (as opposed to addressing only the probability or utility part of the problem).

119 Other logic considerations

12 Quality of input - obtaining complete, accurate, and timely data and judgments.

121 Good data gathering - obtaining complete, accurate, and timely data.

122 Good management of staff/expertise - making staff assignments in a manner that makes best use of the available expertise and facilitates accurate and timely data processing.

123 Posing meaningful questions - requesting the appropriate data and judgments.

124 Good overall input quality - a summary measure of obtaining overall appropriate, complete, accurate, and timely data and judgments.

129 Other input quality considerations

2 Time and cost - the amount of time and cost devoted to the analysis.

21 Elapsed time - the time from the instant that a decision is recognized to the time that a decision is made.

211 Short elapsed modeling time - keeping the time spent on structuring the model low.

2111 First pass - the first time that the model is used.

2112 Additional passes - repeated uses of the model.

212 Fast input assignment - quickly attaching values to input parameters (e.g., values and probabilities).

2121 First pass

2122 Additional passes

213 Fast calculation - quick performance of the calculations needed to determine a recommended decision.

2131 First pass

2132 Additional passes

214 Fast interpretation - ability to quickly interpret the analysis output.

2141 First pass

2142 Additional passes

215 Short overall net elapsed time - fast performance of items P211-P214 above.

2151 First pass

2152 Additional passes

2153 Total - all passes

219 Other time considerations

22 Costs - The amount of executive time and anguish and cash expenses involved in making the decision.

221 Low-cost analysis - performing an analysis cheaply.

2211 First pass

2212 Additional passes

222 Low-cost input assignment - making all required input assignments cheaply.

2221 First pass

2222 Additional passes

223 Low-cost calculation - performing the required calculations cheaply.

2231 First pass

2232 Additional passes

224 Low-cost overall - a low level of overall costs.

2241 First pass

2242 Additional passes

2243 Total - all passes

229 Other costs.

3 Other considerations

31 Activity preceding choice processes - activities that take place prior to considering a decision.

311 Good environment monitoring - monitoring the environment for indications that a problem exists or gathering information to resolve the problem.

312 Good decision identification - recognizing when a decision must be made and what decision is needed.

313 Good option generation - generating the options for choice.

314 Good pre-analysis of anticipated decisions - thinking through future decisions in advance.

319 Other

32 Activity following choice processes.

321 Good decision communication - communicating the decision and any supporting arguments (e.g., to facilitate justifying the decision).

322 Good hindsight evaluation of decision - facilitating an after-the-fact evaluation of the quality of decision.

323 Effective implementation - effectively implementing the choice.

329 Other.

33 Organizational and other non-"choice specific" impacts - impacts that are not concerned with making a decision choice, but that affect more permanent or organizational properties.

331 Improved information processing - improving the recall, correlation, and presentation of relevant data.

332 Improving the command, control, and communication properties of the organization - e.g., making managers behave more responsibly.

333 Improving body of applied precepts - improving doctrinal guidelines.

339 Other.

APPENDIX D

SITUATIONS FAVORING THE USE OF DECISION ANALYSIS

This appendix presents a more thorough examination of the situations favoring decision analysis than is presented in Section 3.1.2. In particular, this appendix examines how each situation category shown in Tables 2-1 and A-1 impact the decision to use decision analysis. As in other sections of this report, references to situation categories are preceded by the letter "S" and references to performance measures are preceded by the letter "P." These references are explained in detail in Appendices A and C, respectively.

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
DECISION SUBSTANCE (S1)	
Basic Situation (S11)	
Current/Contingent Choice (S111)	Current choice (S1111) favors the use of decision analysis because it is certain that the analysis could be used. Since decision analysis is a tool to aid in decision making, its value as an aid is reduced in contingent situations (S1112), where it is uncertain that the decision will ever occur.
Expected Number of Occurrences (S112)	A decision that is expected to recur (S1123, S1124) supports the use of decision analysis because the cost (P22) per analysis is reduced. The amount of advantage gained by recurrence, of course, depends upon both the expected frequency of occurrence and the similarity of the recurring situations because the similarity will determine the amount of modification needed. The expected number of occurrences is, in general, closely related to the current/contingent classification, and the two categories should be considered simultaneously. For instance, a current decision that will occur only once should be considered the same as a contingent decision that has a 50% chance of occurring twice. Both of these situations have an expected occurrence rate of one. (The advantages of a recurring situation may be somewhat reduced if the situation is also characterized by hindsight monitoring, (S166) below.)

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
Operating/Information Act (S113)	This classification is unimportant in itself for determining the appropriate amount of analysis, but it is indirectly important because of its impact on other situational dimensions. For example, the maximum option impact (S144) is typically smaller and the determinability of uncertainty (S162) is typically lower for an informational act because the impact of the informational act is felt through a subsequent operating act. This impact relationship obscures the relationship between the situation category and the analytic taxonomy.
Options (S12)	
Broad/Narrow (S121)	Unimportant
Clear/Fuzzy (S122)	Clearly specified options (S1221) support the use of decision analysis because conceptual completeness is facilitated (P111).
Complexity of Decision Options (S123)	Unimportant
Radical/Adaptive (S124)	A situation involving a radical decision (S1241) supports the use of decision analysis because decision analysis can improve the logic of choice (P11) in situations that are outside of the decision maker's experience. Radical decisions also tend to be difficult decisions. This feature is discussed for (S131) below.

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
Static/Dynamic (S125)	Static situations (S1251) favor the use of decision analysis. However, when decision analysis is favored for other reasons in a dynamic situation (S1252), the dynamic feature supports the use of a large amount of analysis. Since decision analysis is not particularly good at providing conceptual completeness (P111) in dynamic situations, a good analysis requires a large effort.
Decidability (S13)	
Difficulty of Choice (S131)	Difficult choices (S1312) support the use of decision analysis. A basic argument for the use of decision analysis is that it improves the decision quality (P1). In the case of a difficult decision, there is *much room for improvement* because informal decision processes are not very good at addressing difficult decisions.
Unfamiliarity (S132)	Very unfamiliar decision situations (S1322) support the use of decision analysis mainly because of logic-of-choice considerations (P11).
Key Considerations (S133)	If the key consideration is option generation (S1331), decision analysis should not be used. Decision analysis is not good at generating decision options. If the key consideration is information (S1332), no strong case can be made either in favor of or against decision analysis.

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
	If inference (S1333) is the key consideration, use of decision analysis is slightly favored because decision analysis can help produce *sound predictions* (P113).
	If choice (S1334) is the key consideration, decision analysis is strongly indicated because of its ability to improve choice logic (P11).
Stakes (S14)	The stakes involved in the decision is the single most important classification for determining the appropriate amount of decision analysis. Since larger stakes support more decision analysis, only the minimum stakes needed to justify any analysis will be discussed. Alternative definitions of stakes itemized below are *in decreasing order of accessibility* but in increasing order of relevance. In general, the higher the stakes, the less important is cost (P22) and the stronger the case for decision analysis.
Resources Committed (S141)	R.A. Howard's dictum is that 1% of the amount of resources committed to the decision should be devoted to the decision analysis effort.
Cost Swing (S142)	The cost swing is typically about one half of the resources committed. Accordingly, about 2% of the cost swing should be devoted to the decision analysis effort.

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
Value Swing (S143)	A difference between the best and worst plausible outcomes of about $1 million is necessary to justify any decision analysis.
Maximum Option Impact (S144)	The maximum option impact is a more relevant but less accessible measure of stakes. As a rough rule of thumb, the maximum option impact, that is, the dollar equivalent difference in outcome attributable to the choice of the best decision over worst decision (among those which might reasonably be taken), should be on the order of $100,000 (S1442) in order to justify any decision analysis.
Expected Option Impact (S145)	The expected option impact, that is, the maximum difference in expected value between plausible options under consideration, is an even more relevant and less accessible measure of stakes. An expected option impact of about $50,000 (S1452) is required to justify the use of decision analysis.
Expected Irrationality Cost (S146)	The most relevant and least accessible measure of stakes is the expected irrationality cost, the room for improvement in the decision (the concept of irrationality cost is explained more fully in Watson and Brown [1975/1]). The expected irrationality cost necessary to support the use of decision analysis is $20,000.

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
Difficulty of Net Valuation (S151)	Difficult valuation (S1512) supports the use of decision analysis because of the improved logic of choice (P11), which decision analysis allows.
The Rest of the Outcome Valuation Dimensions (S151) to (S156)	Unimportant.
Outcome Uncertainty (S16)	
Number of Uncertainties (S161)	More uncertainties support the use of more decision analysis because of the ability of decision analysis to improve the logic of choice (P11) in the face of uncertainty.
Determinability (S162)	The less determinable the distributions, the stronger the case is for using decision analysis, again because of the improved logic of choice (P11) offered by decision analysis.
High/Low Uncertainty (S163)	A high degree of uncertainty supports the use of decision analysis because of the improved logic of choice (P11) that should result.
Subsequent Acts (S164)	The existence of important subsequent acts supports the use of decision analysis because it can enhance conceptual completeness (P11) in that situation.
Type of Evidence (S165)	Unimportant.
Hindsight Monitoring (S166)	A situation that is characterized by a high degree of hindsight monitoring (S1663) promotes improvements in informal

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
	decision making through the development of an improved body of applied precepts (P333). Thus, hindsight monitoring reduces the need to use decision analysis.
DECISION PROCESS (S2)	
Reaction Time (S21)	In general, a longer reaction time will support more decision analysis because of the time necessary to perform an analysis (P21). However, a contingent choice analysis (A1331) is supported by a short reaction time combined with a long anticipation time.
Analytic Processes (S22)	
Number of Input Sources (S221)	Since conventional, intuitive decision practice has difficulty organizing input from a variety of sources, and decision analysis provides a method for organizing a diverse set of inputs, use of decision analysis can improve the quality of input (P12), especially through the management of staff and expertise (P122); and the logic of choice (P11), especially through effective disaggregation (P112). Thus, a large number of input sources (S2213, 4, 5) supports the use of a large amount of decision analysis.
Analytic Team (S222)	Decision analysis is favored when a group of people are available to perform the analysis (S22212) mainly because of its capacity for effective disaggregation (P112) and good management of staff and expertise (P122).

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
Constraints on Analytic Method (S223)	Obviously, if an analytic method is prescribed (S2231) and the prescribed method is decision analysis, these prescriptions support using decision analysis. On the other hand, if a method of analysis other than decision analysis is prescribed, this argues against using decision analysis. If no constraints are in force (S2230), this distinction has no effect on the amount of decision analysis to use.
Documentation (S224)	Required documentation favors the use of decision analysis because decision analysis promotes improved communication (P332).
Organizational Processes (S23)	
Initiation (S231)	Unimportant.
Responsibility (S232)	Decision analysis is favored in situations in which a tentative decision (S23212) is to be made or where a recommendation is to be made (S23213) because decision analysis can provide good decision communication (P321), effective dissaggregation (P112), and good management of staff and expertise (P122).
Coordination (S233)	Unimportant.
Justification (S234)	A need to justify the decision (S2341, S2342, or S2343) supports the use of decision analysis because of the need for good decision communication (P321).

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Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
Controversial (S235)	Controversial decisions (S2352) support the use of decision analysis because of the need for good decision communication (P321).
Performance Control (S236)	Tight performance control (S2362) supports the use of decision analysis because of a need for improved command, control, and communication (P332).
Rational-Actor Model (S237)	Since decision analysis assumes a rational-actor model, a situation that is a good approximation of the model (S2372) supports the use of decision analysis.
Risk Attitude (S238)	Decision analysis provides the necessary effective disaggregation (P112) in situations in which risk attitude needs to be considered (S2381, S2382, S2383, or S2389).
Decision Maker Characteristics (S24)	
Position in Organization (S241)	A situation with a high-level decision maker (S24113) supports the use of decision analysis mainly because he is in a position that commands more resources (S25); accordingly, time and cost (P2) are less important considerations.
Personal Characteristics (S242)	Decision analysis is indicated when the decision maker has a familiarity with decision analysis (S24212 or S24213) because in this situation decision analysis will promote effective decision implementation

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
	(P323), good management of expertise (P122), and good overall logic (P114) (since familiarity will increase the chances of doing the analysis correctly).
Resources Available (S25)	
Computational Facilities (S251)	The use of decision analysis is supported by better computational facilities (S2512) because they enable less expensive calculation (P223).
Staff (S252)	The use of decision analysis is supported by the availability of a strong staff (S2522) because such a staff is more apt to perform an analysis correctly and improve the overall logic of choice (P114).
Decision Analysis Expert (S253)	The use of decision analysis is supported by the availability of a decision-analytic expert (S2532) because such an expert is more apt to perform an analysis correctly and improve the overall logic of choice (P114).
Decision Maker Availability (S254)	A high availability of the decision maker (S2542) supports the use of decision analysis because, without it, logic of choice (P11) and quality of input (P12) are seriously impaired.
Assessors Available (S255)	Unimportant.
Dollars Available (S256)	High dollar availability (S2563) favors decision analysis because costs (P22) are then unimportant.

Situation Classification	Relationship to the Appropriate Amount of Decision Analysis
Other Decision Processes (S29)	
Negotiation (S291)	Negotiation situations (S2911-2) support the use of decision analysis for reasons of improved choice logic (P11), especially through conceptual completeness (P11) and effective disaggregation (P112). Decision analysis provides a methodology for simultaneously accounting for elements of the problem that otherwise might be handled individually. (For example, an important amount of work done at Decisions and Designs, Incorporated relates to negotiation problems.)

APPENDIX E

TAXONOMIC MATCHING FOR TYPE OF ANALYSIS

This appendix extends the matching concepts of Section 3.1 to the determination of the form of decision analysis to use. In particular, this appendix characterizes each of the analytic options highlighted in Table 3-2 in terms of performance measure generalizations, and it proposes a tentative matching of analytic options onto situations. The appendix shows how the taxonomies can be used at several illustrative levels of analytic choice, for example, deciding to do conditioned assessment or deciding to use the Delphi technique to aggregate probability judgments. It should be repeated that no attempt has been made at completeness in codifying the state-of-the-art of decision analysis. The matching generalizations presented here are purely illustrative.

Each analytic choice considered will be taken in turn and, in each case, the performance characteristics distinguishing the options will be discussed first, followed by discussion of how various situation characteristics bear on the choice between them.

Throughout this appendix, analytic options references are preceded by the letter "A," situation references are preceded by the letter "S," and performance measure references are preceded by the letter "P." These items are described in detail in Appendix B, Appendix A, and Appendix C.

E.1 CONTINGENT ANALYSIS (A1331)[1]

Performance Characterization

Contingent choice analysis requires a large amount of first-pass time (P2151)[2] but provides a fast response on additional passes (P2152). In addition, when reaction time is short (S211), a contingent choice analysis improves both choice logic (P11) and input quality (P12), and improves command, control, and communication (P332) by allowing for incorporation of a senior's values into the analysis.

Situation Classification	Relationship to Contingent Choice Analysis
Current/Contingent Choice (S111)[3]	By definition, contingent analysis requires a contingent choice situation (S1112).
Clear/Fuzzy Options (S122)	Clear options (S1221) allow a contingent analysis to provide a good pre-analysis of anticipated decision (P314). Clear options also enhance predictability (see below).
Expected Number of Occurrences (S112) and Maximum Option Impact (S114)	These two situational characteristics need to be considered together. In general, contingent choice analysis is indicated in situations where its cost (P22) is justified by either a large number of occurrences (S1124) or by a large maximum option impact (S1444).

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[1] Analytic options are described in Appendix B.

[2] Performance measures are described in Appendix C.

[3] Situation characteristics are described in Appendix A.

As a rule of thumb, a contingent analysis should not be performed unless the expected number of occurrences is at least one (S1122) (e.g., occurring once with certainty or occurring twice with a 50% probability). To determine the number of occurrences it is also necessary to consider the similarity of the occurrences; the more similar the situations are, the more the contingent analysis is justified. (As a rule of thumb, three similar recurrences are roughly equivalent to a single identical recurrence.) It is critical that the actual decision is predictable, in that it involves the same considerations that are modelled for a good pre-analysis (P314).

As a guideline, the expected option impact (considering number of occurrences) should exceed $10 million (S1444) to justify the cost (P22) of a contingent analysis. See page 3-3 of Brown et al. (1975) for an illustration of this guideline in a Navy task force commander's decision situation.

Reaction Time (S21)	A contingent analysis is recommended where reaction time is short (S211). In this situation, the analysis can improve the decision quality (P1) by providing a logical framework that considers all available data.
Number of Input Sources (S221)	Contingent choice analyses can improve command, control, and communication (P332) in situations that require several preference (e.g., value) sources to be considered (S2213).

E.2 OPTIMIZATION (A1341)

Performance Characterization

An optimization analysis is characterized by poor decision quality (P1), especially with regard to conceptual completeness (P111), unless the analysis is comprehensive (A221). However, optimization promotes a short interpretation time (P214).

Situation Classification	Relationship to Optimization
Reaction Time (S21)	If reaction time is short (S211), then the time savings (P214) provided by optimization is more important than the loss in decision quality (P1).
Other	If a comprehensive analysis is performed (A221), then optimization is difficult, leading to lower logic quality (P114), and an expensive analysis (P22) if the options are unclear (S1222).
	A controversial decision (S2352) may favor display (A1342), but not to the exclusion of optimization (A1341).

E.3 USE A COMPUTER (A1521)

A computerized analysis tends to involve high first-pass calculation cost (P2231) and long first-pass calculation time (P2131), except for a complex analysis (A213). However, a computer analysis generally involves a low level of subsequent-pass calculation cost (P2232) and short subsequent-pass calculation time (P2132).

Situation Classification	Relationship to Computer Use
Expected Number of Occurrences (S112)	Since a computer offers cheaper and faster performance on subsequent passes, use of a computer is supported by a large expected number of occurrences (S1124).
Maximum Option Impact (S144)	A large maximum option impact (S1444) justifies a large cost (P22) and indicates a complex model (A213). Both of these conditions support a computerized analysis.
Reaction Time (S21)	Since a computer analysis takes a long time to build, days of anticipatory reaction time (S213) are needed. However, since a computerized analysis runs quickly, only minutes of execution reaction time (S211) are needed.
Staff Available (S252)	Some staff support (S2521) is needed to program a computerized analysis.
Other	The costs (P22) and time (P21) of a computerized analysis are not significantly worse than the alternative of a non-computerized analysis if the situation has clear, complex options (S1221, S1236), many determinable uncertainties (S1613, S1623), and many measurable values (S1523, S1532).

A computer is also recommended in conjunction with a complex analysis (A213) and with simulation (A5311).

E.4 COMPLEXITY OF ANALYSIS (A21)

Performance Characterization

A complex analysis can sometimes (for instance, see below) provide a good choice logic (P11) and input quality (P12). However, a complex analysis takes a long time (P21) and is expensive (P22). In addition, a complex analysis provides for good decision communication (P321) by explicitly modelling a large number of important factors.

Situation Classification	Relationship to Complexity of Analysis
Difficulty of Choice (S131)	Choice logic (P11) and input quality are important in a difficult choice situation (S1312). If the situation is also one in which a complex analysis contributes to choice logic and input quality, a complex analysis is recommended.
Maximum Option Impact (S144)	A large maximum option impact (S1444) justifies a high cost (P22) to improve choice logic (P11). A complex analysis is supported if it contributes to improved choice logic.
Outcome Valuation Timing (S155)	A complex analysis can improve choice logic (P11) and input quality (P12) if the timing is late (S1552).
Subsequent Acts (S164)	A complex analysis can improve choice logic (P11) and input quality (P12) if subsequent acts have a high impact on the decision outcome (S1643).
Reaction Time (S21)	A complex analysis requires much time (S213 or S214).
Number of Input Sources (S221)	A complex analysis can improve choice logic (P11) and input quality (P12) if there are several input sources (S2213, S2214 or S2215).

Justification (S234)	A situation that requires justification (S2341, S2342, S2343) requires good decision communication (P321) and thus supports a complex analysis.
Controversial (S235)	Controversial decisions (S2352) require good decision communication (P321) and thus support complex analyses.
Decision Maker's Familiarity with Decision Analysis (S2421)	A decision maker who is very familiar with decision analysis (S24213) can improve choice logic (P11) and input quality (P12) by using a complex analysis.
Computational Facilities Availability (S251)	A powerful computer (2512) can reduce the computational cost (P223) of a complex analysis and thus favors its use.
Staff Available (S252)	A strong staff (S2522) is needed to perform a complex analysis in order to minimize the risk of an erroneous analysis and increase the overall choice logic (P114).
Decision Maker Availability (S254)	A complex analysis can improve input quality (P12) when a decision maker is unavailable (S2540). The complex analysis can perform the disaggregation that the decision maker might otherwise do informally.
Assessor Availability (S255)	Assessors must be very available (S2552) in order for a complex analysis to provide good overall input quality (P124).
Dollars Available (S256)	Because of its cost (P22), a complex analysis requires a large dollar availability (S2563).

E.5 PARTIAL ANALYSIS - INFERENCE ONLY (A2221)

Performance Generalization

An inference analysis is limited in scope (P115) to addressing uncertainty (not values or options). Consequently, an inference analysis costs less (P22) than a full analysis.

Situation Classification	Relation to Inference Only
Key Consideration (S133)	An "inference only" analysis can provide the conceptual completeness (P111), effective disaggregation (P112), and sound predictions (P113) that are necessary when the key consideration is inference (S1333).
Clear/Fuzzy Options (S122)	An inference model can improve conceptual completeness (P111) with fuzzy options (S1221).
Maximum Option Impact (S144)	An "inference only" analysis is a reduced scope (P115) consistent with reduced cost (P22), and thus requires a low threshold of maximum option impact (S1442).
Difficulty of Net Valuation (S151)	Since an "inference only" analysis does not model valuation, conceptual completeness (P111) will be poor unless the valuation is easy (S1510).
Uncertainty Determinability (S162)	An inference model can improve choice logic (P11) when uncertainties are indeterminable (S1621).

E.6 APPROXIMATE ANALYSIS (A231)

Performance Generalization

An approximate analysis can be done quickly (P21) and inexpensively (P22), but it lacks logic of choice (P11) and quality of input (P12).

Situation Classification	Relationship to Approximate Analysis
Difficulty of Choice (S131)	An easy choice (S1311) does not require much improvement in decision quality (P1) and thus supports the use of an approximate analysis.
Maximum Option Impact (S144)	Since an approximate analysis can be cheap (P22), only a low maximum option impact (S1442) is necessary to justify an approximate analysis.
Computational Facilities Available (S251)	An approximate analysis is not complex and is recommended when no computer is available (S2510).
Staff Available (S252)	An approximate analysis is more difficult than a complete one, and thus an approximate analysis requires a strong staff (S2522) in order to control the approximation error and effect good overall choice logic (P114).

E.7 SHORT TIME HORIZON (A3121)

Performance Generalization

A short time horizon switches attention from modelling uncertainty to modelling value in that the value model subsumes uncertainties that are beyond the modelled time horizon.

Situation Classification	Relationship to Short Time Horizon
Difficulty of Net Valuation (S151)	Difficult valuation (S1512) supports the use of a short time horizon, since a short horizon focuses attention on valuation.
Valuation Timing (S155)	By definition, a short time horizon should be used in an early timing situation (S1551).
Uncertainty Determinability (S162) and High/Low Uncertainty (P163)	Low (S1631), determinable (1623) uncertainties support the use of a short time horizon, since a short horizon focuses attention away from uncertainty.
Availability of Assessors (S255) and Dollars (S256)	Low assessor availability (S2551) and dollar availability (S2561) will tend to indicate a simple analysis (A211), which can often usefully incorporate a short time horizon.

E.8 ACTS AS EVENTS (A3132)

Performance Characterization

Modelling acts as events reduces cost (P22) and promotes conceptual completeness (P111), but may make posing meaningful questions (P123) difficult compared with preposterior modelling (A3131). However, omitting an explicit modelling of subsequent acts (A3130) reduces cost even more.

Situation Classification	Relationship to Acts as Events
Impact of Subsequent Acts on Outcome (S164)	A high impact of subsequent acts (S1642 or S1643) supports at least some modelling of subsequent acts (but preposterior even more than acts-as-events).
Other	Modelling subsequent acts as events promotes conceptual completeness (P111) when it is difficult to model informational events or the subsequent analysis needed for preposterior modelling [see Brown (1975)].

E.9 DECOMPOSED VALUATION (A3222)

Performance Characterization

Sometimes decomposed valuation can improve choice logic (P11), especially through effective disaggregation (P112), and input quality (P12). However, decomposed valuation is slow (P21) and expensive (P22). Also, decomposed valuation is limited in scope (P115) to valuation.

Situation Classification	Relationship to Decomposed Valuation
Maximum Option Impact (S144)	As a rule of thumb, a decomposed valuation analysis does not require high stakes, but for larger stakes (e.g., S1444) costs (P22) are less important and decomposed valuation is even more strongly indicated.
Difficulty of Net Outcome Valuation (S151)	Decomposed valuation can help provide conceptual completeness (P111) and effective disaggregation (P112) when outcome valuation is difficult (S1512).
Reaction Time (S21)	Decomposed valuation requires hours of reaction time (S212), but longer reaction time is desirable.
Number of Input Sources (S221)	Decomposed valuation can help effective disaggregation (P112) in a situation with multiple preference sources (S2213 or S2215).
Controversy (S235)	Decomposed valuation can aid good communication (P321) for controversial decisions (S2352).
Computational Facilities (S251)	A computer (S2511 or S2512) is useful, but not necessary, for decomposed valuation.

E.10 SINGLE, ADJUSTED INDEX (A32411)

Performance Characterization

A single, adjusted index promotes good decision communication (P321) because the number is interpretable by a nontechnical user and the number has more information content than a dimensionless utility. If value cannot be reduced to a single index, then insufficient conditions exist for a choice [the situation lacks conceptual completeness (P111)]. An adjusted index is limited in scope (P115) to valuation.

Situation Classification	Relationship to Single, Adjusted Index
Decision Justification (S234)	An adjusted index can provide the communication (P321) needed to justify a decision (S2341, S2342 or S2343).
Controversy (S235)	An adjusted index can help provide the communication (P321) needed for a controversial decision (S2352).

E.11 LINEAR VALUE FUNCTION (A32511)

Performance Characterization

A linear value function promotes good decision communication (P321) because it is commonly used and readily understood. However, a linear value function lacks conceptual completeness unless certain utility conditions are met. Specifically, value dimensions should be additively independent and linear. A linear value function is limited in scope (P115) to valuation.

Situation Classification	Relationship to Linear Value Function
Decision Justification (S234)	A linear value function can help provide the communication (P321) needed to justify a decision (S2341, S2342 or S2343).
Staff Available (S252)	Since a linear value function requires no specialized skills, it is indicated when no staff is available (S2520).
Assessor Availability (S255)	Since a linear value function requires no unusually difficult assessments, only a low level of assessor availability (S2551) is needed.

E.12 MARKOV (SPECIAL FORM) (A3311)

Performance Characterization

A Markov analysis is a compact analysis, which enables inexpensive input assignment (P222) and inexpensive calculation (P223). However, since a Markov analysis is restricted, it may impair conceptual completeness (P111), and, because it requires special skill, a Markov analysis is an expensive analysis (P221). A Markov analysis is also restricted in scope (P115) to uncertainty.

Situation Classification	Relationship to Markov Analysis
Key Consideration (S133)	Markov analysis only addresses probabilities; therefore, it is indicated when inference is the key consideration (S1333).
Difficulty of Net Outcome Valuation (S151)	Since a Markov analysis does not contribute to valuation, it is recommended when valuation is easy (S1510).
Other	A Markov analysis requires a special environmental structure. Specifically, it requires that a time series of stochastically changing discrete variables, and their associated transition availabilities, follow some systematic pattern.

E.13 PARETO (SPECIAL FORM) (A3321)

Performance Characterization

A Pareto analysis can improve conceptual completeness (P111) by allowing a simultaneous analysis of the joint utility function of the parties involved. On the other hand, a Pareto analysis may reduce conceptual completeness (P111) because it does not accommodate the dynamic social aspects of negotiation.

Situation Classification	Relationship to Pareto Analysis
Negotiation (S291)	Pareto analysis addresses the negotiation problem and thus requires a negotiation situation (S2911 or S2912).

E.14 LINEAR PROGRAMMING (SPECIAL FORM) (A3331)

Performance Characterization

When a computer is available (S2511 or S2512), linear programming can provide a low-cost overall analysis (P224) and low-cost calculation (P223), especially in subsequent passes (P2242 and P2232), and can enable fast calculation (P213) and short elapsed modelling time (P211). However, linear programming is slow (P21) and expensive (P22) without a computer (S2510). In addition, linear programming will reduce conceptual completeness (P111) unless restrictive conditions are met. Specifically, the objective function that is to be maximized or minimized and the constraints must be linear. Also, linear programming can enable low-cost input assignment (P222), because it requires little involvement of the decision maker, but it is poor at posing meaningful questions (P123) and does not permit disaggregation (P112) of value or uncertainties.

Situation Classification	Relationship to Linear Programming
Clear/Fuzzy Options (S122)	Linear programming requires clear options (S1221).
Option Complexity (S123)	Linear programming addresses vector options (S1235 and S1236) and is most useful in large vector (S1236) situations.
Difficulty of Net Outcome Valuation (S151)	Linear programming does not contribute anything to determining valuation and does not permit disaggregation (P112). Thus, the situation must be characterized by easy outcome valuation (S1510).
Amount of Uncertainty (S163)	Linear programming assumes certainty and thus requires a low amount of uncertainty (S1630 or S1631).

Computational Facilities Available (S251)	Linear programming requires a computer (S2512) because it is slow (P21) and expensive (P22) without one.
Staff Available (S252)	Linear programming requires a modest staff (S2521), but a strong staff is better (S2522), to ensure an accurate analysis and good overall logic (P114).
Decision Maker Availability (S254)	Linear programming does not require much decision maker availability (S2540) for interaction. This keeps the input assignment costs low (P222).
Other	Linear programming assumes a structured, linear environment.

E.15 FLOATING ZERO BASE (A4322)

Performance Characterization

A floating zero base provides a compact analysis. This allows for low-cost input assignment (P222) (because fewer inputs are required), low-cost calculation (P223) and an inexpensive overall analysis (P224). However, a floating zero analysis is less conceptually complete (P111) if utility is non-linear, and is difficult to communicate (P321). In addition, a floating zero analysis requires more assessment skill, which may produce an expensive analysis (P221). Also a floating zero base is limited in scope (P115) to valuation.

Situation Classification	Relationship to Floating Zero Base
Maximum Option Input (S144)	Because floating zero is inexpensive (P22), it requires only a modest maximum option impact (S1442).
Difficulty of Net Outcome Valuation (S151)	Floating zero requires easy valuation (S1510) because it is difficult, and hence expensive (P22), to apply unless valuation is easy.
Decision Justification (S234)	Floating zero is recommended when decision justification is not needed (S2340) because floating zero is not good at providing the communication (P321) needed for justification.
Staff Available (S252)	Floating zero is difficult and thus it requires a strong staff (S2522) to ensure good overall logic (P114).

E.16 CONDITIONED ASSESSMENT (A441)

Performance Characterization

Conditioned assessment sometimes promotes logical choice (P11), especially through effective disaggregation (P112), and quality input (P12) (see below). However, conditioned assessment is time consuming (P21) and costly (P22).

Situation Classification	Relationship to Conditioned Assessment
Maximum Option Impact (S144)	The stakes threshold for performing conditioned assessment is low (S1442) but, because of cost of conditioned assessment (P22), the larger the stakes (S144), the stronger the case for using conditioned assessment.
Determinability of Outcome Uncertainty (S162)	Conditioned assessment promotes logical choice (P11), especially through effective disaggregation (P112), and input quality (P12) when outcome uncertainty is indeterminable (S1621).
Reaction Time (S21)	At least hours of reaction time (S212) are needed for conditioned assessment but a longer reaction time is desirable (S213 or S214) because elapsed analysis time (P21) is of less concern with a long reaction time.
Number of Input Sources (S221)	Conditioned assessment can improve input quality (P12), especially through good management of staff/expertise (P122) when there are several substantive sources (S2214 or S2215).
Computational Facility Available (S251)	A computer (S2511, S2512) is useful for conditioned assessment.

Staff Available (S252)	A modest staff (S2521) is necessary but a strong staff is preferred (S2522) in order to ensure good overall logic (P114).

E.17 BAYESIAN PROBABILITY UPDATING (A4421)

Performance Characterization

A Bayesian probability updating model promotes effective disaggregation (P112) and a low-cost overall analysis (P224). However, a Bayesian updating model may lead to poor input quality (P124) because it is often difficult to elicit the necessary prior probabilities and likelihood functions. Also, Bayesian updating is limited in scope (P115) to inference.

Situation Classification	Relationship to Bayesian Probability Updating
Key Consideration (S133)	Bayesian probability updating is recommended when the key consideration is inference (S1333) because Bayesian updating addresses inference.
Staff Available (S252)	Bayesian updating is difficult. Therefore, a strong staff (S2522) is needed.
Other	Bayesian updating assumes a perceptual structure that includes prior probabilities and likelihood functions.

E.18 REFERENCE GAMBLE (A4531) (ELICITATION TECHNIQUE FOR VALUES)

Performance Characterization

The reference gamble elicitation technique can provide conceptual completeness (P111), but the technique makes it difficult to pose meaningful questions (P123). In addition, the reference gamble technique rates low on decision communication (P321), data gathering (P121), and involves high input assignment cost (P222). Also, the reference gamble technique is limited in scope (P115) to valuation.

Situation Classification	Relationship to Reference Gamble Technique
Decision Justification (S234)	Although the reference gamble technique scores low on decision communication (P321), an important performance measure for decision justification, its demonstrably superior conceptual completeness (P111) makes the reference gamble technique good for decision situations requiring justification (S2341, S2342 and S2343).
Staff Available (S252)	Reference gamble elicitation is difficult. Therefore, a strong staff (S2522) is required to ensure good overall logic (P114).
Assessor Availability (S255)	The reference gamble technique requires a high degree of assessor availability (S2552).

E.19 DELPHI (A45411)
(GROUP ELICITATION TECHNIQUE FOR PROBABILITIES)

Performance Characterization

The Delphi technique involves pooling the opinions of several probability assessors with limited interaction.

Situation Classification	Relationship to Delphi Technique
Number of Input Sources (S221)	The Delphi technique addresses the problem of several uncertainty sources (S2214).
Other	The Delphi technique limits interaction among assessors and provides the assessors with anonymity. Thus, the Delphi technique removes inhibition and allows better use of staff expertise (P122) where the status of the assessors is heterogeneous. However, if data is heterogeneous, then the Delphi technique reduces input quality (P12) by inhibiting useful interactions. See Fischer (1975) for further information on the Delphi technique.

E.20 SIMULATION (ANALYTIC DEVICE) (A5311)

Performance Characterization

Simulation is expensive when compared with doing nothing, but it provides less costly analysis (P221) and less costly calculation (P223) than an identically structured extensive form analysis. On the other hand, simulation communicates less effectively (P321) than extensive form. In addition, simulation lacks conceptual completeness (P111) due to errors of approximation, and simulation is restricted in scope (P115) to probabilities.

Situation Classification	Relationship to Simulation
Maximum Option Impact (S144)	Since simulation is expensive, it is indicated in situations with large stakes (S1444).
Other	Simulation may be indicated in conjunction with a complex structure (A213) or a conditioned assessment model (A441).

E.21 STEP-THROUGH SIMULATION (A531111) (ANALYTIC DEVICE)

<u>Performance Characterization</u>

Compared with regular simulation (A531110), step-through simulation provides:

- o greater conceptual completeness (P111),
- o lower-cost overall modelling (P224) and input assignment (P222) but greater demands on the decision maker (for the same level of conceptual completeness), and
- o better decision communication (P321) (because step-through requires the decision maker to get involved in the analysis).

Situation Classification	Relationship to Step-Through Simulation
Outcome Valuation Timing (S155)	Step-through simulation is adapted to improving conceptual completeness (P111) for chronological sequences, and chronological sequences are significant only in situations with late evaluation dates (S1552).
Determinability of Uncertainty (S162)	Step-through simulation improves conceptual completeness (P111) most when uncertainties are indeterminable (S1621).
Decision Justification (S234)	Because step-through simulation involves the decision maker in the analysis, it improves the communication (P321) needed for justification (S2341, S2342, S2343).
Staff Available (S252)	Step-through simulation is a difficult technique, and it requires a strong staff (S2522) to ensure good overall logic (P114).

Assessor Availability (S255)	Step-through simulation can improve conceptual completeness (P111) only if the assessor is available (S2552). (Step-through shifts the weight of effort from the analyst to the assessor).

APPENDIX F

CONCEPTUAL FRAMEWORK FOR MATCHING

This appendix presents a conceptual framework for the matching task. Specifically, an analogy is drawn between the matching task and the task of formulating a regression problem. This analogy is presented only as a conceptualization of the matching problem and does not imply that the matching task can actually be formulated in a mathematical representation.

Formally, we can visualize the matching task as formulating a regression or other estimating function of the form:

$$\underline{A} = f\ (\ \underline{P}\ ) = \Phi(\ \underline{S}\ )$$

where

$\underline{A}$ is the appropriate values (choices) of the analytic option vector,

$\underline{P}$ is the vector of all relevant performance requirements for a given situation,

$\underline{S}$ is the (much larger) vector of all relevant situation characteristics, and

f and Φ are the appropriate mapping functions.

In general, $\underline{P}$ and $\underline{S}$ are unavailable because the size of the vector is too great for practicality because the elements in the vector are not accurately measured. Typically, what we have available are $\underline{P}'$ and $\underline{S}'$, more manageable sets of estimated performance requirements and situation characteristics, such as those proposed in our performance measure and situation taxonomies.

As in regular regression practice, we are faced with the problem of implicitly or explicitly formulating an estimate of $\underline{A}$, $\hat{\underline{A}}$, of the form:

$$\hat{\underline{A}} = \theta\ (\ \underline{P}',\ \underline{S}'\ )$$

where θ is an <u>estimate</u> of the appropriate mapping function that minimizes the expected error, $E(\ \underline{A} - \hat{\underline{A}})$, subject to the cost of measuring and implementing θ, $\overline{P}'$. $\overline{S}'$.

The practical counterpart of this approach is that our matching generalizations may incorporate both performance measures and situation characteristics.

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